CUBICLES FOR DAIRY COWS IN LOOSE HOUSING
- Dimensions and partition design for more comfort and cleaner cows

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Rapport 236
Report 236

Swedish University of Agricultural Sciences
Department of Agricultural Engineering
Building Design Section

Uppsala 1999
ISSN 00283-0086
ISRN SLU-LT-R-236-SE

PREFACE

In loose housing the cubicle is an extremely important element of the cow's environment, affecting its comfort, cleanliness and health. Cubicles must provide a clean, comfortable lying area for the cows and they should be able to enter and leave cubicles easily and lie-down and rise without interference. Other considerations are freedom from injury, cubicle cleanliness, bedding requirements, labour and durability.

Careful attention to the design of cubicles and their maintenance is most important. Improperly designed cubicles may lead to cows lying incorrectly and manuring in the cubicle or instead lying in passages or elsewhere. Wet, contaminated cubicle beds are likely to increase the incidence of environmental forms of mastitis. Contaminated beds will also increase the dirtiness of the animals resulting in more labour for cleaning before milking as well as risks of decreasing the milk quality. A clean udder is of great importance e.g. in voluntary milking systems (robot-milking).

A wide variety of cubicle designs, more or less suitable, have been introduced around the world in past years. Many designs have been abandoned after a short time of use, others have become accepted. In many cases local tradition have lead to a special design being dominant. For manufacturers and companies selling cubicle equipment this variety of designs may create obstacles resulting in unnecessary high prices. Thus a goal must be to reduce the wide variety of produce.

The work reported in this publication was initiated and financed by Alfa-Laval Agri AB. The main objectives were to compile international research results and recommendations concerning the design of cubicles. A test series should be carried out where commercially available as well as a prototype cubicle were evaluated to determine if any "ideal" design could be identified. The research was carried out as an extended thesis-work at the Department of Agricultural Engineering, Building Design Section by MSc-student Henrik Carlsson. Most of the field data was collected at the Kungsängen Animal Husbandry Research Centre where especially PhD-student Jan Olofsson was most helpful. His assistance as well as that of Mr. Bengt-Göran Mårtensson, Alfa-Laval Agri AB and the technical staff at Kungsängens Research Centre involved in the rebuildings of the cubicles are acknowledged.

Uppsala, January 1999

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SUMMARY

Health and welfare of loose-housed dairy cows in cubicle stalls is related to the design of the cubicles. Problems with lack of cleanliness, disturbed behaviours and cow health still occur in modern dairy housing systems. The purpose of this work was to compile present knowledge of cubicles, especially the partition design. The main objective was to recommend a cubicle partition that would facilitate natural behaviours and maintain clean and healthy dairy cows. The study was made both as a literature review and as experiments. Researchers, Alfa Laval Agri AB market divisions and farmers were contacted throughout the study. Even though bedding materials and construction of the cubicle floor is of importance, it is only briefly mentioned in this study.

A survey of research and recommendations made on cubicle design was carried out in the literature review. A summary of cubicles on the market and around the world today was also made. Field studies of preference, hygiene and lying down behaviour of dairy cows were used to evaluate how well cows performed in some various cubicle types. I each study, cows were monitored using time-lapse recording. The hypothesis was that partitions with obstructed side zones perform better than partitions that facilitate space sharing to the side. Another part of the experiment was to examine whether the cubicle training rail could be redesigned in order to facilitate more natural behaviours of cows, but still have functionality.

The experiment compared occupancy and hygiene levels in two cubicle designs. Two already existing popular partition types were combined with brisket boards and training rail. Sixteen cows had free access to 8 cubicles of each type for a study period of two weeks. A hygiene study was also made of the cubicles, determining the level of hygiene in each cubicle by observing cubicle dirtiness twice a day during one week. Four cubicle designs were examined concerning the lying down and rising behaviour. Two cows were randomly chosen for the intense behavioural study. They were moved between the cubicle types (after an adaptation period) and monitored for 24 hours in each of the four cubicle types.

The overall conclusion made from the experimental part is that long-term experiments need to be done to evaluate how cubicle design interacts with cow cleanliness and comfort. The behaviour of cows in cubicle systems corresponds to many constraints that need to be defined and held equal. However by observation, it seems to be easier to evaluate how well the animals perform natural behaviours in the cubicles than making conclusions about cleanliness and injuries.

According to the results observed, a high placement of the training rail would add cubicle comfort. Anyhow, the use of a shoulder brace in the cubicle did not add lying comfort in the present experiment. A cubicle partition that facilitate more space sharing to the side in the front seems to be more attractive for the cows, and does not interact with a natural lying down behaviour. The back of the partition should guide the cows to lie down in a position that facilitate cubicle cleanliness. Thus, the hypothesis that partitions with obstructed side zones perform as well as a partition that facilitates space sharing to the side could not be confirmed.

BACKGROUND

Generally, cows are today housed in tie stalls or loose. Bigger herds, easier management and animal behaviour requirements have led to increased utilisation of loose housing systems. Straw yards, feeding cubicles and cubicles are the three major ways to house loose dairy cows indoors. The frequently mentioned advantages offered for cubicles, in relation to the other systems, include less maintenance and lower utilisation of bedding, lower labour requirements, greater cow comfort, greater cow cleanliness and less cow injury. Construction and dimensions of dairy cattle cubicles also affect the overall success of loose housing systems.

During the last 30 years a lot of emphasis and research has been made on the housing of loose dairy cows. Still, the problem with soiled and injured cows remains. The increase of mastitis caused by environmental pathogens has been attributed to modern dairy housing systems (Sumner, 1991). Modern milking routines do not allow much time for teat preparation. The cleaning of dirty cows, particularly before milking, is both laborious and ineffective. It is of importance to keep dairy cows, and especially their udders, clean and dry in the barn to prevent problems. Mastitis, lameness and hoof problems along with ineffective management are factors of great concern associated with economic and ethic values. A well working stall environment does not affect animals negatively or cause additional management work (Hedrén, 1971*a*).

A successful housing system must provide for the spatial and behavioural needs of cows, overcoming a number of constraints that form the ambient environment for the animals. Animal welfare is related to the basic needs of resting, feeding, drinking, locomotion, social conditions, hygiene and injuries. Herd health is strongly correlated to the ambient environment given by air quality, ventilation and light. The importance of management of dairy cows by the herdsman should not be neglected. Milking routines, barn cleaning, feeding and so on, are also important parts of a well working system.

Internationally, and also in Sweden, there are big differences in cubicle design although some standards can be formed: Dimensions, partition design, floor, bedding, training rail, brisket boards are different. These differences are caused by changes in production, but also as a consequence of tradition, laws, requirements, advice, and market requirement.

Purpose

Alfa Laval Agri AB initiated the present study. The purpose of the work was to compile present knowledge of cubicles, especially partition design, and recommend a design of cubicle partition that would facilitate natural behaviours in dairy cows, maintain clean and healthy cows, and meet the latest demands in modern dairy production. If required, a new standard on cubicle design was to be formulated and Alfa Laval Agri would produce the proposed partition.

Restrictions

The work was limited to cubicle design except for the bedding and construction of the cubicle floor. The latter are briefly mentioned and some facts are given about dimensions and recommendations according to the literature. In addition, the work does not concern layout of cubicle barns.

Method

A survey of the cubicles on the market and around the world today was made through researchers and Alfa Laval Agri market divisions. By making a literature review, knowledge in the subject was obtained and the research and studies concerning cubicle design were summarised. In addition, field studies and visits to different cubicle houses on farms were made together with interviews. Different designs were compared and analysed for advantages and disadvantages.

In order to evaluate the relative merits of different designs, some experiments on hygiene and animal behaviour were conducted with support from Alfa Laval Agri and Kungsängen Research Centre. The aim was to obtain direct evidence on cow comfort and responses to various cubicle types that would contribute and support the recommendations and conclusions made in the survey.

LITERATURE REVIEW

Health and welfare of loose housed dairy cows in cubicle stalls is related to the design of details such as partitions, brisket boards and training rails (Cermak, 1987). In a study of cubicle housing, Schleitzer & Thrabert (1993) found that even if the cubicle base dimensions were almost optimal, 2.3-2.4 m in length and 1.2 m in width, 10 percent of the cows had some kind of problems to lie down or rise in a natural fashion. They related the problems to partition design. In addition, milk production and management of dairy herds have certain requirements, especially on hygiene and cleanliness. Designing cubicles that contribute to all demands and will work in all kind of situations is very complex. Additional experiences are given from studies on excoriation injuries made in Denmark (see Table 1).

It is considered that different housing systems for dairy cows could represent well working systems if individual factors are satisfactory. Herlin (1994) found that other factors than the housing system alone determine the level of animal welfare, e.g. the design of the facilities and equipment. In addition, previously recommended dimensions of cubicles are not suitable for the cows of today (Gaisford, 1996) since breeding selection and better feeding have increased their size and the increased milk production has changed the animals' behavioural pattern.

Table 1. *Excoriation injuries on dairy cows (Clausen et al., 1996)*

	Fore knee, %	Hock, %	Neck, %	Body, %
Cubicles	10.7	6.1	5.7	2.9
Feeding cubicles	14.2	6.9	0.4	1.0
Tie stalls	12.7	10.9	0.6	0.2

Today, the main reason for not having functional cubicles appears to be high economic costs. However, inadequate dairy housing equipment may cause costly teat treads and mastitis, which make expensive equipment worthwhile (Hedrén, 1971*a*).

When designing dairy housing equipment it is most important to consider the demands of the cows and the given requirements. Due to the high milk production of dairy cows, cubicles need to be designed in a way that they are attractive for cows to use frequently. To accomplish this, performance terms should be considered, and observation of the behaviour of cows should be the emphasis rather than comparison of equipment data (Cermak, 1998; McFarland, 1998).

The cow and her natural demands

Naturally, when on grazing the cows stay together in family herds of 15 to 20 animals (Jensen, 1993). The groups are adjusted in hierarchy or precedence. The animals have a strongly correlated behaviour for grazing and lying down. These behaviours are dependent on season, daylight, weather and other ambient factors.

Cows are strongly motivated to rest, feed, drink and move around. According to Wiepkema (1982), those behaviours are motivated like a process to work towards a goal from a present situation. Proper functional consequences are to be achieved and accomplished by completing the whole cycle of demands to decrease motivation. Control ability and predictability are important according to Wierenga (1991) and there should be opportunities for synchronisation, to avoid frustration and competition. A correct stress level also contributes with positive effects on the animals (Owen et al., 1994).

Lying times

The constant demand of cows for lying is of high priority (Metz, 1984; Metz & Wierenga, 1984) and is referred to as an inelastic demand (Wierenga, 1991). When neither searching for feed, drinking, making social contact nor cleaning itself, time is spent on lying down. Most of the rumination occurs in the lying position. Süss & Andreae (1984) summarised the literature and found that dairy cows were lying down for 9 to 12 hours per day, divided into 10 to 20 periods per day.

Great differences in total lying time are due to many natural reasons like age, stage in lactation, oestrus cycle, social factors, synchronisation and individual physical factors. When housing loose cows, bedding, partition size, partition layout, micro climate, feeding, milking, overcrowding and cleaning also have an influence on the time spent lying down (Wierenga & Hopster, 1991).

The individual total lying time per day for each dairy cow seems to be fixed in a defined system, but the duration of each lying period is dependent on the same factors mentioned above and is about 60 to 80 minutes on average. Cows move quite often during the lying period, the head swinging and the legs changing position. The reason is the large body weight that gives a high pressure on those parts that are in contact with the ground. Blood flow and disposal of rumen gases also make the cows move around (Owen et al., 1994). Natural lying positions are shown in Figure 1.

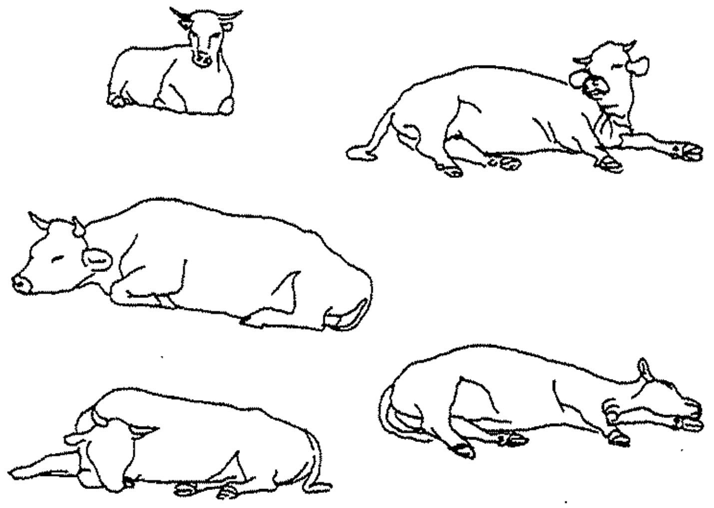


Figure 1. *Natural lying positions (Schnitzer, 1971).*

When cows are ruminating in a lying position they have their head raised and rest on their chest bones and either left or right hock. Usually the head is held perpendicular to the body since other positions of the head prevent eructation from the rumen and swallowing of saliva (Hedrén, 1971*a*). Other positions are used when "deep sleeping", REM (Rapid Eye Movement), which is needed for about 30 minutes a day divided into 6 to 10 periods of 4 minutes duration (Sambraus, 1978). Cows spend about the same time lying on each side, only with a slight preference for the left side (O'Connell et al., 1989).

Lying down and getting up

The rising and lying patterns of cows are congenital behaviours that are very difficult to change. First the cow searches for a good spot to lie on by slowly moving forward, sniffing and looking. The head swings close to the ground, from one side to the other. Cows desire some requirements of the surroundings when searching for a place to lie down on. The place that is preferred should be soft, dry, clean and almost flat. Naturally, on pasture, hills are favoured as lying places. If the ground is not level, cows seem to prefer lying with their fronts higher and their backs against the slope (McFarland, 1992).

When preparing to lie down, the hindquarters are put forward a little. One of the forequarters is bent and the knee is placed at the ground. The other forequarter soon follows. The hindquarters are moved a little forward to the side and the body is bent a little. The hindquarters are laid down with the head and neck as counter balance. However, the last half-meter is more or less a free fall to the ground. During the end of this movement one of the hindquarters is lifted a little and put under the pelvis while the body is lowered down by the other quarter. The forequarters are placed on the ground by bending the knees and are balanced by swinging the head and neck upwards a little.

Naturally, a well-performed lying down movement requires fixed placement for the hoofs and enough vertical head and body space. About 0.6 to 0.7 m are needed for the lunge, beyond the body length, and the whole pattern normally takes 15-20 seconds (Schnitzer, 1971; Hedrén, 1971*b*).

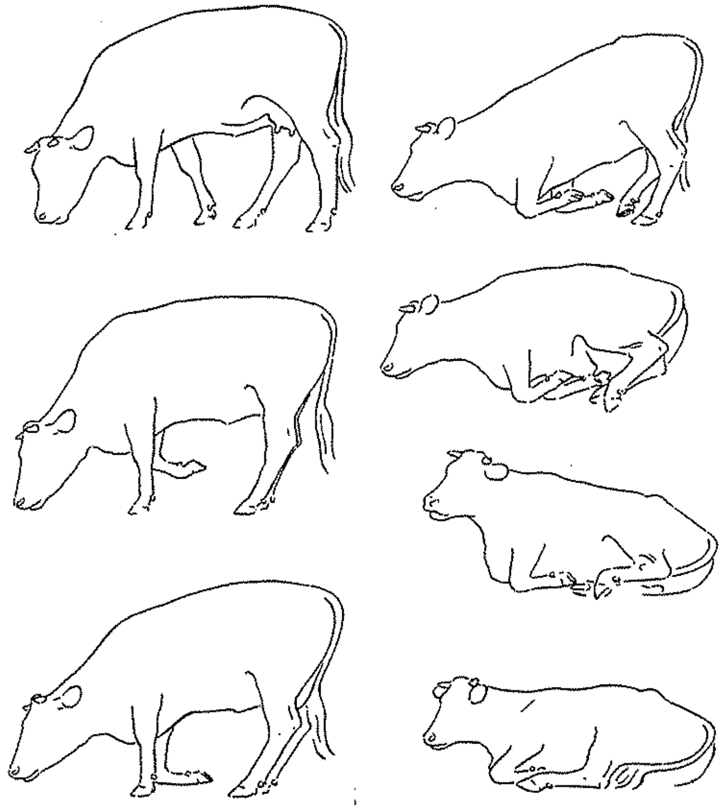


Figure 2. *Lying pattern (Schnitzer, 1971).*

Starting from the normal lying position the cow's rising pattern is normally divided into several phases. In the most natural lying position, the cow has the front body resting on the chest bone and the front knees are bent. The back of the body lies a little to the side and one hindquarter is lying under the body while the other one is straightened along the side (see Figure 3).

First the clear hindquarter is pulled back so that the hoof will be alongside the udder. The cow lunges forward and up on her fore knees to transfer the weight from the hindquarters that are turned a little up from the side-lying position. The hindquarters are lifted first by the clear leg and then with help from the other one. To balance the lift of the hindquarters the head and neck are lunged forward, as far as possible. The cow makes a couple of small steps to balance the hindquarters. One of the forequarters is straightened at the same time as the head and neck is thrown up. The other front quarter is also straightened and the cow will stand up. Normally one small step forward is required (Schnitzer, 1971; Hedrén, 1971*b*).

The rising cow will use a lot of energy during the rising action movements and normally it takes 5 to 6 seconds to get up. Fixed placement for the hoofs and about 0.7 to 1.0 m is needed for the lunge, beyond the body length.

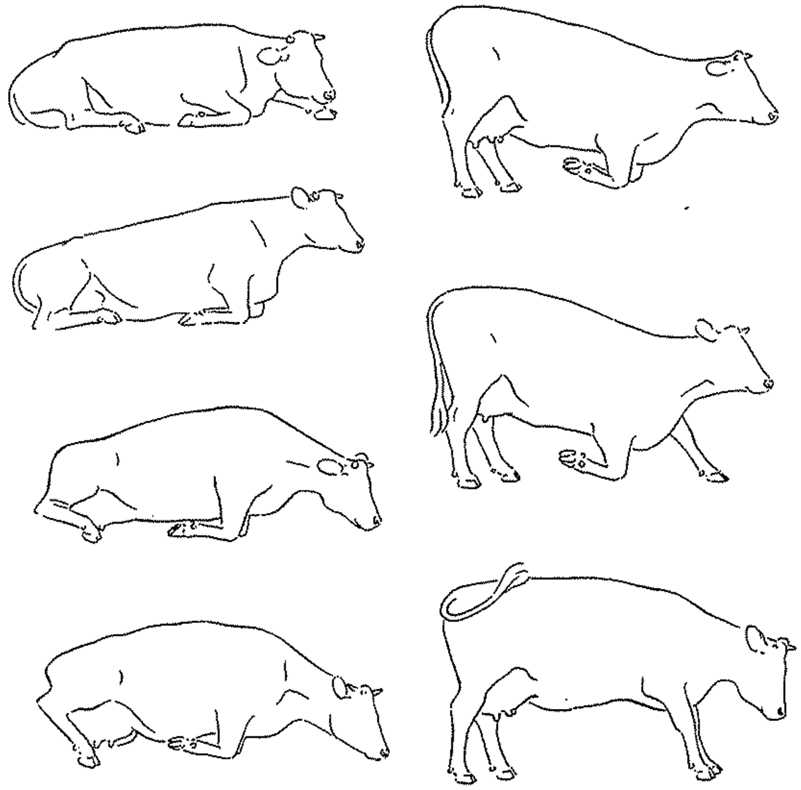


Figure 3. *Natural movement of rising cow (Schnitzer, 1971).*

Group dominance - Social space

The herds of cows are divided in to a hierarchy or degree of precedence. This enables conflicts to be solved without major aggression. The hierarchy is established by threats and not often by open conflicts. When the relations between two individuals have been determined, the relation is very stable. Horn size, sex, age and body size are important signals when the hierarchy is established, but also oestrous cycle and animal health can be considered as factors (Jensen, 1993).

When housing cows the behaviour of an individual animal is very strongly related to its position in the social hierarchy. The hierarchy of a group of cows could be linear but is very often more complex. Normally, high ranked cows have priority over low ranked cows at the feeding table and in the cubicles. Cows prefer to have a space of at least 1 m from each other if not protected by some physical barrier (Sumner, 1991). However, in loose housing dairy barns, this distance is related to how crowded the pen is.

Body dimensions of cows

When designing equipment for dairy cows housed in cubicles the measurements of the animals need to be considered. Measurements are more important than the weight, since body shape can vary considerably. Depending on design and functions in question, different measurements are needed. To determine the performance of cubicles, especially body length, height and width are important.

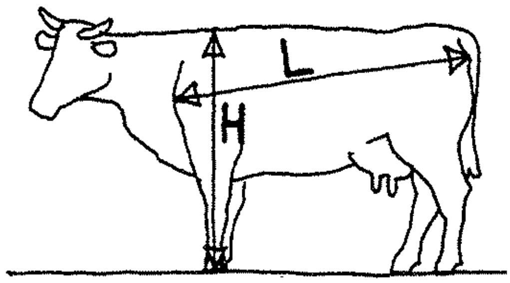


Figure 4. *Body dimensions of cows (Owen et al., 1994).*

Normally, live weight and age of the cows are known. Even so, those figures need to be converted into dimensions that are useful for the design. There is a great variation between different livestock breeds. Owen et al. (1994) processed cow size data, and formulated an overall feasible standard on heavy breeds where different breed sizes were combined.

Table 2. *CIGR (International Commission of Agricultural Engineering) standard of dimensions of cows, Owen et al. (1994)*

Weight (kg)	Height (m)	Length (m)	Width (m)
550	1.35	1.61	0.50
650	1.39	1.69	0.55
750	1.42	1.75	0.60

Still, those recommendations should be compared with the variation that occurs between the different breeds. Data from a Danish study, comparing 658 cows, will represent data for heavy breeds in Scandinavia (Danish Friesian Cattle and Danish Red and White Cattle).

Table 3. *Correlation between body weight and dimensions of breeds in Denmark, after Krohn et al. (1995)*

	Weight (kg)	Height (m)	Length (m)
Heavy breed	650	1.41	1.64
Jersey	450	1.25	1.30

Apart from differences between livestock breeds, there are very big individual differences when comparing cows from the same breed, and even in the same herd. Statistics performed on more than 5000 cows in Germany have revealed that even genetically similar animals within one breed have considerable variations in body measurements (Bockisch, 1993). Owen et al. (1994) suggest that equipment should be designed based on the dimensions of the 20 percent heaviest animals.

History of cubicles

Our society has housed cows for a very long time in different ways. The oldest documentation of cows housed in stalls is preserved on a limestone relief in Mesopotamia and is about 4500 years old (Mehler & Heinig, 1968). Conclusively tied cows have been housed for thousands of years, probably with longer or shorter periods of grazing and throughout this period the stalls have not changed much from the figure shown below. However, gates, other base materials and partitions have been added.

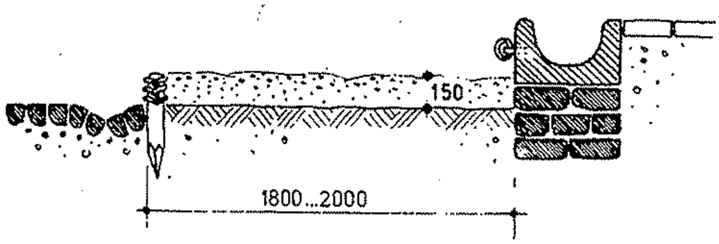


Figure 5. *Old tie stall with sand floor (Mehler & Heinig, 1968).*

It was not until 1960 that barns were designed with cubicles for loose-housed dairy cows in the way we know them today. Independent of each other, Evans in the UK designed a cubicle measuring 2.02 x 1.11 m while in the USA Oien built a slightly larger one sized 2.4 x 1.2 m (Sumner, 1989). They both used wooden planks as dividers and cubicles like these are still in use, except that the measurements have changed a little.

The aim to date has been to make the cubicles more comfortable for the cows. Today, the partitions are more extensively made of steel pipes instead of wooden planks. Suspended partitions are used to accomplish more comfort and to make it possible to maintain and change the bedding and base material easily. From using only a concrete floor with bedding, softer materials such as mats, mattresses and sand are now used to make a more comfortable lying area.

Definition of a cubicle

In the cubicle system, the cubicle rows provide individual lying spaces for the cows, whereas feeding and milking are done elsewhere. A cubicle combination includes the cubicle floor, the bedding layer and the partition. Ideally, cubicles with well-made ambient environment are designed in a way that the cows will experience a protective place and will keep their natural behaviours. The cows should be able to perform basic needs of standing, lying down, lying and rising comfortably in the cubicle zone. Manure and urine should fall in the alley and disturbance from the neighbouring cows should be reduced to a minimum (Hedrén, 1971*a*).

Cubicle functionality is connected with several factors. Ideal conditions are low utilisation and little maintenance of bedding, low labour requirements, high cow comfort and cleanliness, freedom from injury, durability and ease of removing sick or dead cows (O'Connell et al., 1991*b*; Bickert & Ashley, 1991). The primary factors influencing lying pattern and cow comfort in a cubicle barn are the number of cubicles, the floor design, disturbance possibility, cubicle placement in the barn and the layout of the cubicle partitions (Potter & Broom, 1987; Wierenga & Hopster, 1991). Additional factors are frequency of scraping slurry and bedding cubicles, milk yield, diet of the cows, width of passages or use of slatted passages, slurry handling system and type and quantity of bedding (Cermak, 1988). According to Metz (1984) and Metz & Wierenga (1984) it should be possible for all animals to lie down all the time to avoid competition in the communal areas.

In addition, airflow and ventilation of livestock facilities are essential. According to Sumner (1991) and Owen et al. (1994) healthy cows have surplus body heat. Furthermore, in hot weather, cows show preference for cubicles with good air movement. Hot weather coupled with inadequate air movement through cubicles may lead cows to lie elsewhere. Most often they will seek out a wet alley surface or other highly contaminated area in an effort to increase the rate of heat dissipation from their bodies (Bickert & Ashley, 1991). In cold conditions dairy animals can exist satisfactorily in properly ventilated barns where air movement is slow and relative humidity is low. Cold or even severe climate has no negative consequences when cows are kept dry and properly fed, especially if the animals have adequate bedding in the cubicles (Bickert et al., 1995).

Dimensions of the cubicle lying area

According to Irish & Martin (1983), the cubicle lying area should be big enough for adequate rising and lying down behaviour, not so wide that cows lie diagonally and short enough for defecating in the alley. More often general guidelines are given as follows: The cubicle should be long enough to hold the cow comfortably, with her udder protected, but not so long that manure is deposited in the back of the cubicle. The cubicle should be wide enough to contain the cow comfortably, yet not wide enough to allow her to turn around and contaminate the front of the cubicle. Even so, cubicle size needs to be adjusted to actual animal size (McFarland & Graves, 1995; Owen et al., 1994).

The partition must allow the animal to share space with neighbouring cubicles, when needed, in order to allow the rising cow to generate adequate swing and move forward the centre of gravity of the body during the rising movement. Most injuries are self-inflicted and are caused by narrow cubicles, low cubicle partitions or the lower cubicle rail set to high (Cermak, 1988). Cermak (1988) summarised some data regarding injuries and their causes resulting from inadequate cubicle design, see Table 4. Bockisch (1993) also reports conclusions on various injuries related to inadequate cubicle design.

Long term investigations on cubicle design related to udder health have mainly been made by veterinarians and commonly refer to tie stalls. Ekesbo (1966), Schmidt-Madsen (1978) and Nygaard (1979) found indications of positive effects on udder health from longer stalls. However, stalls were generally shorter than stalls of today and the results are not always applicable to the current cubicle dimensions.

Grommers et al. (1972) found no effects on length or width of stalls on teat treads, while Bakken (1982) found that the incidence of clinical mastitis increased with wider stalls. However, there were no significant results on the sub clinical mastitis. Østerås & Lund (1988) found similar complex associations between size of stalls and udder health. Later, Østerås (1990) failed to find any statistical significant factors related to the design of the stalls.

Ekman (1998) found no correlation between udder health and cubicle dimensions. However, the structure and the condition of the cubicle floor are of great importance for the comfort of cows, for their ability to rise without treading on their teats, and for providing a clean and reasonably soft lying area. Conclusively, the cubicle floor material is more important in Swedish dairy barns today as long as the dimensions of the lying area and the construction of other technical components such as ties or partitions are satisfactory.

Table 4. *Injuries and causes by inadequate cubicle design (Cermak, 1988)*

Cow injuries and behaviour / Likely causes		Narrow cubicle	Short cubicle	Bottom rail low	Bottom rail high	Top rail low	Protruding curb	Training rail set more than 500 mm from front	Low tail rail	Head-to-head division rail set to high	Broken concrete floor	Uneven hard floor	Slippery floor	Lack of bedding	Brisket board incorrect	Rough/new concrete
Swelling	Knee							*	*	*	*	*		*		*
	Hock	*	*				*				*	*		*		*
	Pelvis	*		*	*											
	Abdomen			*												
	Shoulder	*		*						*			*		*	
	Pin Bone		*				*						*	*		
	Neck								*							
Bruised ribs		*		*												
Cut teats		*	*			*		*	*	*	*	*	*	*		
Rising front first			*		*		*			*	*		*		*	
Difficulties rising		*					*	*	*	*	*		*		*	
Lying over a curb		*	*					*								

Length

The cows require enough space for their body to lie down in the cubicle. Owen et al. (1994) uses an equation to calculate the cubicle resting length.

Cubicle resting length = 0.92 x L + 0.15 m

where L is the length of the cows (as defined in Figure 4) and 0.15 m is the space required for making postural changes when lying. Cubicle length should be measured as the figure below shows.

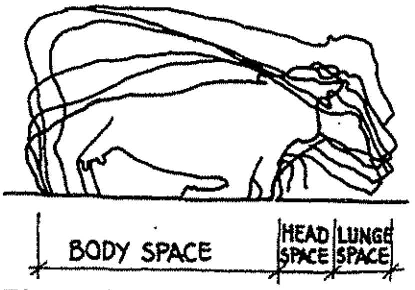


Figure 6. *Measurements of a rising cow (Owen et al., 1994).*

In addition to body space, the cows require headspace during lying but also for the lying and rising movements. If space sharing is available, Owen et al. (1994) use one equation and when forward lunge is necessary and no space sharing is available, another equation is used. The space sharing could be into an opposite or adjacent cubicle.

Head + Lunge space = 0.32 x H, when space sharing is available
Head + Lunge space = 0.56 x H, non space sharing
where H is height at the withers on the cows.

It is calculated that a cow weighing 650 kg will require 1.70 m body space and an additional 0.45 m when space sharing, or 0.80 m when non space sharing is available. Providing space for the forward lunge, the whole cubicle length needs to be about 2.50 m, all in accordance with recommendations given by the CIGR and using cow dimensions from Table 2 (Owen et al., 1994).

Inadequate cubicle length is the main reason why some cows refuse to use cubicles (Cermak, 1987; Sumner, 1991) and cubicles that provide sufficient lunging space are preferred (Kelly et al., 1993). In addition, dairy producers have noticed increased acceptance by cows when solid front barriers were removed to allow forward lunging (McFarland & Gamroth, 1998) and observations indicate that cows prefer to lunge forward, rather than to the side, given the opportunity (Bickert & Ashley, 1991; McFarland, 1992; McFarland & Gamroth, 1998).

Total lying times are also related to the length of the cubicle. Wander (1976) and Cermak (1987) found that lying times get longer when the total cubicle length is changed from 2.10 m to 2.50 m. Brestenský et al. (1996) also found longer lying times with longer cubicle resting length, and when comparing brisket boards placed at different distances from the rear curb he found that 1.8 m littered boxes had the cleanest cows, using Holstein breed.

Width

Generally, cubicle width is measured from the centre of one partition to the centre of the next partition. CIGR (Owen et al., 1994) use the following equation to describe the required cubicle width.

Cubicle width = 0.83 x H
(Maximum width is 0.90 x H) where H is the height at withers.

Tillie (1986) noted that cows are not used to lying close to each other. Observations in deep litter barns indicated that cows put a distance of approximately 0.9 to 1.5 m between themselves. In cubicle barns the cubicle partition represents a physical division, which permits closeness without aggressive interactions.

Research has shown that wider cubicles give more comfort and longer lying times. Wander (1976) and Cermak (1987) found that the lying times get longer when the width is changed from 1.05 to 1.20 m. Gwynn et al. (1991) changed the width from 1.0 m to 1.2 m, which resulted in longer lying times. Gwynn et al. (1993) later found that width has higher priority than length among heavy cows. Cermak (1988) compared cubicles with 1.0, 1.1 and 1.2 m width, with the result that a clear width of 1.2 m was preferred.

Recommendations on length and width

Summarised recommendations for guidance when designing cubicles are shown below.

Table 5. *Recommendations given by Cermak (1987)*

Cow body weight, kg	Width, m	Length, m
575	1.20	2.16
625	1.20	2.20
725	1.20	2.28

Table 6. *Irish & Martin (1983)*

Cow body weight, kg	Width, m	Length, m
545	1.14	2.16
635	1.22	2.20
725	1.22	2.28

Table 7. *CIGR, Owen et al. (1994)*

Cow body weight, kg	Width, m	Length, m
550	1.12	2.06
650	1.15	2.10
750	1.18	2.21

Common for Tables 5 and 6 is that all cubicles should be 0.25 m longer if forward lunge is necessary and for Table 7, 0.35 m should be added.

Table 8. *Minimum requirements according to Swedish Animal Welfare Regulations (L100, 1993)*

Cow body weight, kg	Width, m	Length, m
500	1.10	2.00
650	1.20	2.20
>650	1.30	2.30

All cubicles should be 0.15 m longer if forward lunge is necessary.

Slope

Longitudinal

A gradual slope helps to position the cows and provide drainage of the cubicle floor. Dairy cows seem to prefer lying with their front slightly elevated. Cubicles are normally constructed with 2 to 6 percent inclinations, and according to recent observations in the USA, 6 percent slope tends to be favoured when new installations are made (McFarland & Gamroth, 1994). Cubicles with too little slope, i.e. below 2 percent, make it easier for cows to move forward when lying in the cubicles (Krohn et al., 1995). This usually leads to dirtier cubicles and makes it more difficult for the cows to rise. However, a brisket board would be a means of retarding the cows. Cubicles with a well performing slope, i.e. 4 percent, make the cows move forward or backward, when lying and when changing their lying position (Owen et al., 1994; Krohn et al., 1995).

When the cubicle floor is made of less durable materials, such as a base with sand or sawdust, the slope may change during utilisation and it is important to maintain the right level of bedding material. A high slopes of the cubicle floor also results in higher bedding consumption and requires more frequent bedding of the cubicles. However, cows standing with four feet in high sloped cubicles will have their backs further out in the alley, which means that they will defecate and urinate away from the cubicle floor.

Lateral

Cows seem to prefer lying with their backs upward the slope. Consequently, if the longitudinal slope is too steep they will tend to lie diagonally to the slope. However, if the cubicle floor has a slight lateral slope of 3 percent the cows will place themselves lying on the same side with their back up-slope. This position gives headspace and minimises the risk of teat treads, since most of the cows are lying in the same direction (McFarland, 1992). However, cows have a demand for lying on both sides for about the same length of time. This means that they probably will try to change cubicles for changing the side to lie down on.

There are several additional factors influencing which side that is chosen. Depending on stall layout, cows will have a preference for lying with a favourable overview and with their heads in well-ventilated spots. Cows do not like to see each other when lying and normally they lie down in groups with their backs in the same direction. Gwynn et al. (1993) extended too short cubicles in an existing barn by installing the partitions diagonally, like a herringbone. The cows were lying with their backs towards the front of these cubicles.

Brisket board

The function of a brisket board is to define the border on the floor between the body space and the headspace when lying. McFarland & Gamroth (1994) suggest that the brisket board should be as high as 0.2 to 0.3 m, and it should be designed to follow the contour of the cow's brisket and neck and therefore be angled 30 degrees forward from the vertical. According to Blom (1981), a high (more than 0.15 m above cubicle floor) and sharp brisket board will increase injuries to the fore knees.

Owen et al. (1994) is of the opinion that a brisket board is necessary when having cubicles without space sharing to the side. The neck rail will discourage the cows from moving too far forward when standing and the brisket board will prevent the cows from lying too far forward in the cubicle.

According to McFarland (1992), the brisket board will prevent injuries, hinder cows from getting caught, keep them clean and keep them back while resting. However, brisket boards are only recommended for the Dutch-type (a cubicle that provides space sharing to the side in the head zone) if a forward lunge is provided for (McFarland & Gamroth, 1994).

According to Hedrén (1971*a*), the brisket board exerts a forced control on the cow and emphasises the shoulder brace as an alternative. He refers to a combination of brisket board and crib curb in tie stall barns. A gully in the cubicle floor just in front of the cubicle resting area or a "pillow" made from straw could be alternatives to the brisket board.

Partition design

The partition should guide the cow into the cubicle and protect the cow (McFarland, 1992). It should prevent the cows from standing and lying diagonally in the cubicle, which will lead to teat treads, space sharing of the cubicles and defecating at the back of the cubicle (Hedrén, 1971*a*). Provided that the length and width are adjusted to the cow's size, a number of designs of partitions are satisfactory (Sumner, 1991; Gaisford, 1996). Both in the front and between the lying areas the partition should be designed not to hinder the cows from lying down and rising (Wierenga & Hopster, 1989).

Partition height

The height of the partition is measured from the highest point of the divider to the cubicle base at the rear curb. The top rail of the divider should be placed near eye level when the cow enters the cubicle and act as a visual barrier guiding the cow into the stall (McFarland & Graves, 1995).

The partition should also be high enough to discourage the cows from turning around (Irish & Martin, 1983). Cows often turn in cubicles where the top rail level is 0.9 m or less (McFarland & Graves, 1995). Owen et al. (1994) recommends that the top rail of the partition should be at the same level as the training rail and uses the following equation to determine the level.

$0.75 - 0.85 \times H$
where H is the height at withers.

The height and shape of the lower rail raise more questions. It should help to position the cow and discourage her from lying sideways or diagonally in the cubicle. It should not interfere with the movements needed for rising, or create an entrapment hazard. If the lower rail is set too low the cow can catch her legs under the rail (Tillie, 1986).

The most common recommendation is that the lower rail should be placed 0.3 to 0.45 m above the rear curb (McFarland & Graves, 1995). Owen et al. (1994) recommends that the partitions should have three unobstructed open area zones.

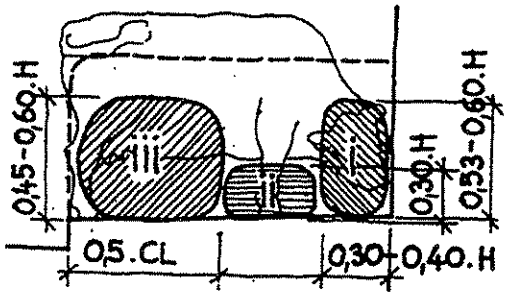


Figure 7. *Three free zones in the cubicle (H = Height at withers) after Owen et al. (1994).*

Figure 7 shows a cubicle where the cow must lunge to the side or into the cubicle opposite, i.e. straight in front of, the cow's own cubicle. (i) is the head zone. (ii) is the zone for controlling lying position. (iii) is the zone for pelvis freedom preventing injury to hips and ribs.
If no space sharing is available or not preferred, the head zone should be extended in length 0.25 to 0.30 x H. However, the partition could be without the free head zone if the forward lunge length is long enough (Owen et al., 1994). Also Bickert & Ashley (1991) and McFarland (1998) point out that if enough forward lunge space is provided there is no need for a side lunge.

Partition length

The partition should be long enough so that the cows are unable to walk behind it on the cubicle bed, but short enough not to disturb the cows in the alley (Irish & Martin, 1983). Accurate spacing helps to reduce the chance of impact between partition and cow as she enters and exits the cubicle, neither will it interfere with work in the alley, such as slurry scraping (McFarland & Graves, 1995). The alley also needs to be wide enough for the cows to orient themselves into the cubicles and remain undisturbed (McFarland & Gamroth, 1994).

Owen et al. (1994) recommend that the partition should be a maximum of 0.4 metres shorter than the cubicle length, whilst McFarland & Graves (1995) recommend 0.2 to 0.3 m, which is the more common recommendation also among salesmen. However, this horizontal distance from the rear curb to the rear end of the partition is impossible to follow regarding partitions with support at the rear curb.

Shape of the partition

There are many different types of partitions that more or less meet the recommendations and that the cows accept. The cubicle partition should be selected based on cow size, dimensions of the barn and the preference of the dairy producer (McFarland & Graves, 1995). For instance, bedding storage or a service passage in front of the cubicles may influence the choice of partition design.

Front and rear support

Early partitions are made of wood and usually consist of two or three horizontal boards supported by two vertical posts embedded in the cubicle base. Today, metal partitions are available but the shape is almost the same. Two or three horizontal bars or diagonal boards are supported at the front and near the rear of the cubicle (McFarland & Graves, 1995). The big advantage with these partitions is that usually less front support is necessary. However, the rear support increases the risk of injury and entrapment while it also discourages maintenance of the cubicle bed and usually rusts off in too short a time (McFarland & Graves, 1995).

The modern versions of these partitions have been modified for better comfort in accordance with research results. O'Connell (1989) showed that the Dutch comfort partition was preferred compared with the Newton Rigg. These are two very commonly used partition types, especially on the British Isles (see Appendix 1). According to Gwynn et al. (1991; 1993) and Gaisford (1996), the lower rail should always be placed between 0.35 and 0.45 m above the cubicle beds and could, with many advantages, be made of a rope. A bottom rail of an elastic material reduces the risk of injuries to hips and pinbones. Especially for cows that are housed in too small cubicles, a flexible bottom rail is a very good way to make old cubicles more comfortable.

Middle support partitions

Middle support partitions have gained popularity since the disadvantages with front and rear supports are decreased. By supporting the partition more in the middle of the cubicle the cows will not get trapped nor suffer injuries from the rear support while maintenance is facilitated and rusting reduced. Especially the Mushroom design (see Appendix 1) and similar versions provide well designed zones for space sharing.

U-shape

Totally suspended partitions are gaining in popularity. Suspended partitions are easily installed and make regular maintenance of the cubicle bed more convenient. Compared with partitions supported at the cubicle floor they also reduce the entrapment hazard to a minimum (McFarland & Graves, 1995).

In the USA, 2.25-meter U-loop partitions are widely used together with a brisket board (Bickert, 1994). Provided that the cubicle is properly sized to allow forward lunging, and sloped to encourage correct cow positioning, the partition is satisfactory. The lower rail should be at a height of 0.40 m above the base to prevent cows from getting trapped or bruising the rib cages (Sumner, 1991).

Some other models are also referred to as U-shaped even if they are supported at the cubicle base. See Appendix 1. These partitions are supported in the very front of the cubicle base and just in front of the brisket board or along the cubicle resting area. They are commonly used in, e.g. France and Switzerland.

Dutch-type

As mentioned earlier, the modern trend is to minimise the amount of rail work or other rigid materials in order to prevent cows from getting trapped. By opening up the partition at the front and chamfering it at the back, cows are able to lunge to the side and share more space with their hips. The Dutch-type or MSU (Michigan State University) type was developed after research made in the early 90's, according to McFarland & Graves (1995).

O'Connell et al. (1991*b*) conducted experimental studies with different kinds of partitions and found that cows have a preference for the Dutch-type compared with others. In a first study, the Dutch Comfort and a Mushroom type were preferred to Dutch-type and Newton Rigg. The Dutch-type caused problems with trapped cows. However, in another study Dutch-type was preferred to Dutch Comfort and a Mushroom type. The Dorsdunn and Newton Rigg was less favoured (see Appendix 1). The conclusion was that cows sense space and choose designs with more space sharing (O'Connell et al., 1991*a*).

However, the design needs to be carefully worked out, since Gwynn et al. (1991) report that cows became jammed also in the Comfort type partition. The Dutch type allows easy lunging to the side but a brisket board is recommended (McFarland, 1992) especially if the cows can work themselves forwards while lying. Today, suspended partitions are chosen together with mats and mattresses for economic reasons (Gaisford, 1996), apart from the reasons for better comfort.

Wide-span

Another popular partition is the Wide-span. This partition has a lowered bottom rail near the front of the cubicle to provide adequate side lunging space. It is widely used in the USA but is becoming more and more popular in Europe. In the Wide-span partition cows have very free positioning and will often lie slightly diagonally, but when used together with a brisket board it works well (McFarland, 1998).

Board at the base

By placing a rounded board at the floor under the partition, the cows will lie straighter in the cubicle (Beckman, 1998). In tie stall barns, the wood board has successfully complemented the partition, leading to less space sharing between cubicles (Hedrén, 1971*b*).

A board at the base under the partition might, if not properly designed, be an obstacle for the cows when lying. However, it might also make the cubicle more comfortable according to Hansson & Wallander (1991), who reported that a square iron bar surrounding the cubicle lying area at floor level kept the bedding more in the middle of the cubicle.

Support and material

The partitions should be easy and quick to move if a cow becomes caught. In addition, easy support will also encourage replacement of bent or broken partitions. As mentioned above, support at the rear curb is not to be recommended. A rear anchor leg boosts the chance of injury and obstructs maintenance (McFarland, 1992). The partitions should also be made without sharp edges, since the risk of excoriation then increases (Blom, 1981). By following proper cubicle design recommendations the partition is rarely exposed to high forces.

Some swinging partitions are in use but if the cubicle is properly designed this property should not be necessary. Swinging partitions are, e.g. when the Wide-span partition is supported with springing coupling at the front and the training rail is hanging free above it. For long service life of cubicles and satisfactory performance, the support should not interfere with the cow's lunging space or air circulation. Fastener strength should be adequate to withstand the abuse of impact between partition and cow and service of the barn. Protection against rust must also be considered, especially when the partition is supported in the cubicle floor.

Training rail

The training rail or neck rail has the purpose to discourage the cow from positioning herself too far forward in the cubicle when entering, and to encourage her to back up in the cubicle when rising. Another purpose is to give the partitions lateral support. The neck rail must be adjustable.

It is essential that the training rail places the cow in the correct position but is no obstacle when rising. The cow prefers to position all four feet on the cubicle bed before she lies down. The cow should not crawl into the cubicle and should be able to stand and ruminate in the cubicle. If the rail is placed too low or too far back, cows may be reluctant to enter, may lie diagonally on the cubicle bed, or lie too far back. If placed too close to the front, or too high, cows may lie too far forward in the cubicle making the rear of the cubicle dirty and/or making it more difficult to rise (McFarland & Graves, 1995). When used together with a brisket board the training rail could be placed higher without reduced function.

The training rail should be smooth and massive. A steel pipe or a wood rail are preferable while thin cables are not recommended (McFarland, 1992). A floating rail or use of a nylon band might result in fewer injuries to the neck but gives less support for the partitions.

There are many recommendations on how the training rail should be placed, sometimes depending on if it is placed together with a brisket board or not. Owen et al. (1994) recommends that it should be placed at the same distance as the cubicle resting length or 0.1 m behind it. It should have a height of 0.75-0.85 x H (where H is height at withers). The advantage of a training rail is occasionally discussed (McFarland & Gamroth, 1994). A shoulder brace would be a fully satisfactory option.

Rear curb

The rear curb is the border between the lying area and the alley. The cubicle floor should be raised above the dunging passage to ensure that no cow will back into the cubicle and to discourage cows from lying only partly in the cubicle. A high rear curb makes the cow find her lying place more defined and she will get less dirty on the tail, but if it is too high, cows may be reluctant to enter. Observations show that cows dislike a rear curb that is 0.3 m or higher (McFarland & Gamroth, 1994).

According to the Swedish Standard (SS 95 10 17) the rear curb should be 0.15 m when slatted floor and 0.20 m when having a scraped alley. When using a scraped or flushed alley, McFarland & Graves (1995) recommend that the rear curb should be 0.2 to 0.3 m high. Also Owen et al. (1994) suggest a high curb to keep the manure from overflowing into the cubicle during scraping, when having long access and dunging passages. When having a slatted floor, 0.15 to 0.20 m is recommended.

If the cubicle floor is not levelled with the rear curb, moisture and manure will be kept in the cubicle. To keep the bedding layer in place a wood board, rubber flap, slopes or plastic pipe could be recessed in the base. However, this would retain manure and urine and require more maintenance (McFarland & Graves, 1995) and a properly drainage. Cubicle boxes with straw, sawdust and sand litter are in use today and require special maintenance.

Hansson & Wallander (1991) found that the cows using cubicles with a rubber flap or squares steel bar at the curb showed most chasing-out behaviour, probably due to more bedding remaining in those cubicles. To reduce the risk of injuries, the edges of the rear curb should be sloped or rounded.

Head to head arrangements

When cubicles are arranged head to head the opposite cubicle could be partly used for lunging space. But if placed too close, cows will refuse to lie towards each other (McFarland & Gamroth, 1994). When using head-to-head cubicles, Owen et al. (1994) recommend that the total length of the cubicle should be 0.92 x L + 0.15 + 0.32 x H (where L is body length and H is height at withers). To hinder the cow from walking or moving through the front of the cubicle a rail should be placed at a minimum height of 0.55 x H at the border to the opposite cubicle.

Cubicle bed and maintenance

Results of free choice experiments have shown that cows prefer dry, soft beds to hard surfaces (Cermak, 1988). However, the floor must support the cow and resist hollowing caused by the cow's hooves. A relatively flat surface allows the cow to lie down and rise more easily and lie more comfortably, which means that if the cubicle floor is made of less resistant material hollows need to be filled periodically. Owen et al. (1994) indicate that the manure handling and storage system will help to choose the bedding material. Short fine bedding will tend to reduce the amount of bedding material dragged into the dunging passages.

Early studies demonstrated the benefit of daily removal of cubicle bedding in reducing bacterial populations (Sumner, 1989). Owen et al. (1994) recommends that the cubicles should be inspected twice a day and wet bedding and manure should be removed. Clean, dry bedding should be added twice a week. Cubicle cleanliness is also very dependent on the frequency of alley scraping.

Discussion

The forward lunge is essential in a natural behaviour. By opening up a too short cubicle in the front the cows may rise in a more natural way and with a more natural duration. They will also have a higher preference for such cubicles and will have longer total lying times. This also means that injuries related to rising and lying down patterns will decrease. However, longer cubicles still require that the cows position themselves correctly. A well-chosen inclination of the cubicle floor combined with a brisket board will help to accomplish correct positioning. The disadvantages will be that longer partitions require accurate stability and the support of the partition will get more complicated, especially if it is suspended. From an economic perspective, the total building cost will become higher due to the increased total building area.

By using a brisket board, cows will position themselves better when lying and the movements during the lying period are reduced. Observations have shown that cows move considerably when resting (McFarland, 1998). When used together with a brisket board, the training rail becomes less important and could be positioned and designed more comfortably. The disadvantage of the brisket board is that the cow's ability to lie in all natural positions will be reduced, especially in the position with straightened fore quarters. In addition, cows of different sizes will require that the brisket board should be placed at different distances. If not designed correctly it will cause injuries to the fore quarters.

Some research has shown increased incidence of mastitis with the use of wider cubicles. By using a narrower cubicle the possibility for the cows to lie diagonally in the cubicle will be reduced and the possibility for the cows to turn around is hindered. A narrower cubicle makes the cubicle less attractive and gives shorter total lying times. Rising and lying down patterns may also be disturbed and excoriation and teat treads will increase as the encroachment in neighbouring cubicles occurs. Depending of partition design, a less wide cubicle will probably interfere with the partition assignment; only to guide the cow into the cubicle.

The suspended partitions have many advantages if correctly designed. The maintenance of the cubicle base and the bedding layer is simplified and rusting is reduced. It provides an open construction especially at the bottom of the cubicle. Additionally, it gives flexibility to easier change the width of the cubicle. The disadvantages are that the suspended partitions require accurate support in the front of the cubicle and that the partitions need stabilisation from the training rail.

By using partitions with obstructed zones in the front, the cows will be forced to lie straighter in the cubicle. The possibility for the cows to get obstructed and to interfere with the animals in the neighbouring cubicles is reduced. In addition, the cows will experience a more protected individual lying place and the disturbance from neighbouring cows will be reduced. If the partition does not provide space sharing to the side, no side lunge is available and the cubicle requires a well-dimensioned forward lunge space. In this context it should be noted that, cows lunge to the side occasionally to compensate a diagonal lying position. The cows have preference for not lying too close to each other. Even so, experiments have shown a preference for open partition constructions. Cows naturally swing the head to the side when lying down and with more material in the partition the natural behaviours will be disturbed.

By placing the training rail higher above the cubicle base, the cows will experience a more attractive cubicle that gives fewer injuries. There will be a possibility to stand more naturally, with all four legs in the cubicle. The head can be lifted, facilitating natural rumination in a standing position. Since defecating and urinating are done both in lying and standing positions (Hedrén, 1971*a*), the higher training rail needs to be combined with a brisket board.

By using the CIGR-recommendations, two different ideal cubicle partitions could be discerned. Calculated on a 650 kg dairy cow, the design is approximately as shown in Figure

8 where the recommended open area zones are exactly followed.

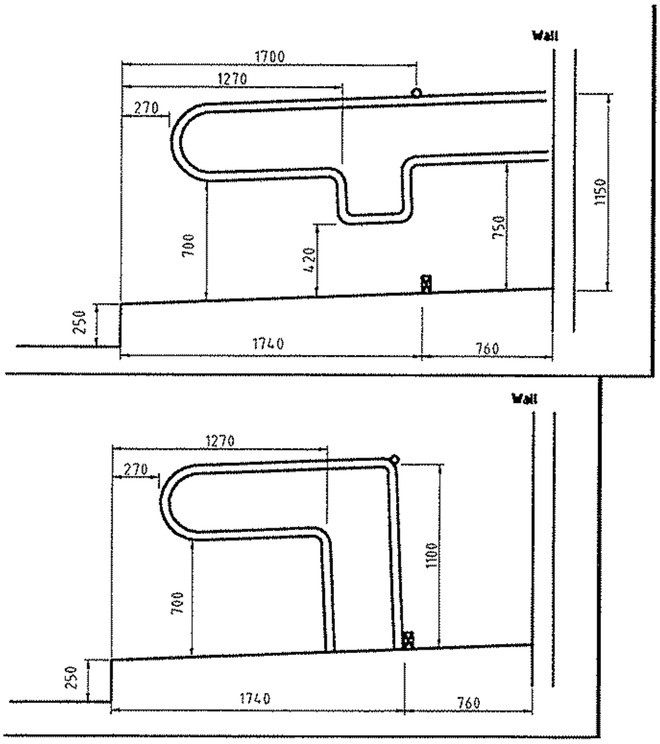


Figure 8. *Ideal partition design, after Owen et al. (1994).*

Conclusions

When designing cubicles it is most important to provide for adequate length and width. The partition design is the next task. No partition can compensate for inadequate bed size.

The cubicles should be designed according to the following:

- Forward lunge should be provided for natural rising.
- The training rail should be placed as high as possible for acceptance and natural standing position.
- The partition should be designed in a way that it helps to position the cow but gives as much free space as possible. Suspended partitions are preferred.
- Brisket boards help to keep cows in position but will interfere with natural behaviours.

Ideal cubicle design – summarised recommendations

Based on a 650 kg heavy breed dairy cow.

- The rear curb should be high enough for the cubicle to stay clean. It should provide an edge for slurry scraping, and prevent cows in the alley from backing into the cubicle. A too high curb will make cows reluctant to enter. However, when too low, cows are not able to define their lying area. 0.2 to 0.25 m is recommended, the lower distance when the floor is drained.

- The cubicle width is dependent on partition layout. A cubicle wider than 1.2 m will allow space for the cow to lie diagonally, with increased risk for injuries and dirtiness.
- The cubicle resting length should correspond to the body length plus some space for making postural changes when lying. 1.7 m is recommended.
- The headspace length should be sufficient for forward rising and 0.8 m is recommended.
- The total cubicle length will consequently be 2.5 m.
- The brisket board should not be higher than 0.15 m and have a forward inclination of a maximum of 30 degrees from the vertical in order not to injure the cow or form an obstacle. The brisket board should be placed at 1.7 m horizontally in front of the rear curb.
- The cubicle downward slope should be 4 percent to accomplish a well-drained cubicle base and keep the cows lying against the rear curb.
- The cubicle floor should be soft, clean and dry. However, firm enough for hoofing. The material should be non-slippery, hygienic and maintained with suitable bedding material.
- The horizontal distance between the partition and the alley should be 0.25 m in order not to interfere with work or cows in the alley but still position the cow when entering the cubicle.
- The training rail should be placed 1.2 m above the cubicle base and just behind or at the same horizontal level as the brisket board.
- The partition top rail should be at eye level of the cow when she enters the cubicle and will be suitable when placed 1.2 m above the rear curb.
- The partition bottom rail should be placed so it positions the cows. However, it should not interfere with the cow's rising pattern or her ability to share space with the legs. Three recommendations satisfy this requirement:
  1. CIGR (see Figure 8) recommend three free zones.
  2. The general recommendation is to have the bottom rail placed 0.35 to 0.45 m above the cubicle base.
  3. The Wide-span type of partition will interfere with the hip zone of the cow, however it is compensated by more space sharing at the front.

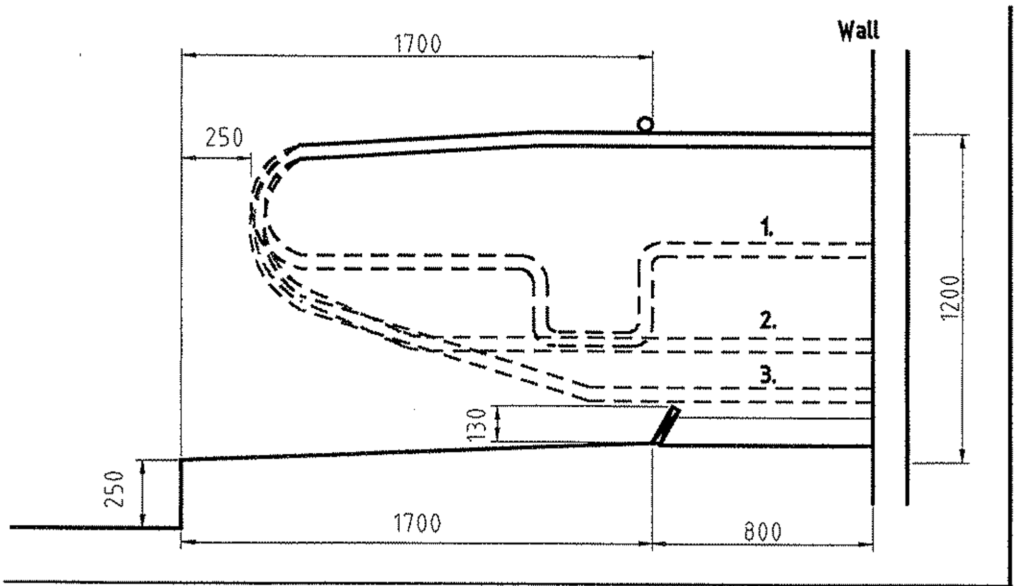


Figure 9. *Ideal cubicle design – summarising recommendations.*

EXPERIMENTAL PART - COMPARISON OF CUBICLES FOR DAIRY COWS CONCERNING PREFERENCE, HYGIENE AND LYING DOWN BEHAVIOUR

Introduction

The aim of the experiments was to compare various cubicle designs. Studies of preference, hygiene and lying down behaviour of dairy cows were used to distinguish how well the various cubicles performed. In order to evaluate the relative merits of cubicles of various designs, the monitoring of cattle behaviour has been shown as a useful method of obtaining direct evidence of cows comfort and responses to various cubicle types (Metz & Wierenga, 1984; O'Connell et al. 1989, 1991*b*). The experimental part presents experimental data on cubicle usage by groups of dairy cows given access to cubicle partitions of different designs with varying potentials for sharing lateral space. In addition, different kinds of training rails were tested.

Some hypotheses were made, mainly from the conclusions of the literature review. In an existing barn the cubicle base dimensions were formed almost as the summarised recommendations suggest. Hence, the hypothesis was that partitions with obstructed side zones perform as well as a partition that facilitates space sharing to the side. Another part of the experiment was to examine whether the cubicle training rail could be redesigned in order to facilitate more natural behaviours of cows, but still have functionality.

Materials and methods

Three experiments where conducted at Kungsängen Research Centre, Swedish University of Agricultural Sciences, Uppsala, during April and May 1998. The experiments were carried out in one part of a cubicle house using one row of cubicles that were equipped with different partitions. All experiments were conducted with the ratio one cow per cubicle. The cows were in mid-gestation, of different ages, body weights and milk yields. A group of 16 Swedish Red-and-White cattle were used in the experiments and milking was done twice a day in a milking parlour. The weights varied from 450 kg up to 720 kg and height at withers and body length varying from 1.29 to 1.43 m (median = 1.35) and 1.53 to 1.76 m (median = 1.64), respectively.

In all experiments, the body resting length, from the rear curb to the brisket board in the cubicles, was 1.70 m and the cubicle width 1.20 m. The total cubicle length from the alley to the wall in front of the cubicles was 2.50 m. The floor slope was 0.06 m from the front to the rear of the lying area and the rear curb height was 0.15 m off the scraped alley. The concrete cubicle floor was abundantly strewed, twice a week, with sawdust and the alley was cleaned with automatic scraper three or four times a day. The cubicles were scraped down and bedding levelled twice daily. The total mixed ration was given three times a day while some extra hay was added once a day. There was access to water at both ends of the cubicle row. Evaluation of different cubicle design was carried out using studies of preference, hygiene and lying down / rising behaviour. The methods used in the experiments mainly follow previously used methods described by Herlin (1997). In each study, cows were monitored using time-lapse recorders.

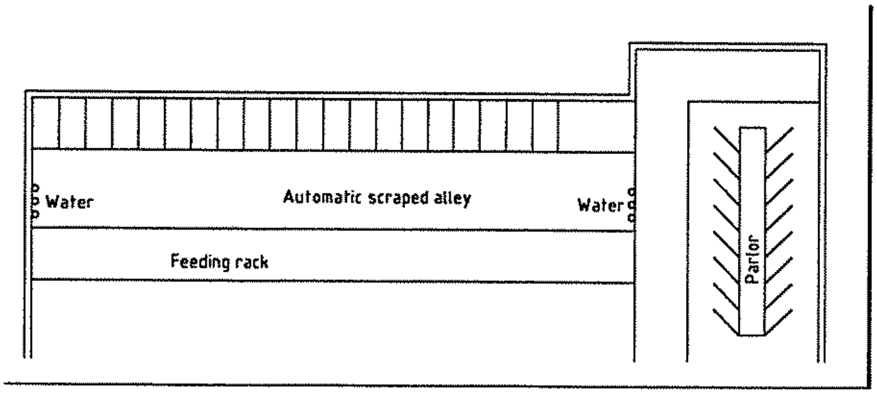


Figure 10. *Layout of the experimental cubicle barn.*

Experimental design

Preference and hygiene studies

The experiment compared occupancy and hygiene levels in two cubicle designs, Stabile and Thurgi partition (see Figure 11). Two already existing popular partition types. Sixteen cows had free access to one row of 16 cubicles divided into equal blocks of 8 Thurgi cubicles and 8 Stabile cubicles. The Thurgi partitions were combined with a sloped brisket board and a training rail that had the shape of a wave. The Stabile partition had a brisket board with no inclination and a common straight training rail. The unclassified cubicle in the middle of the row, where one partition of each type met, was closed.

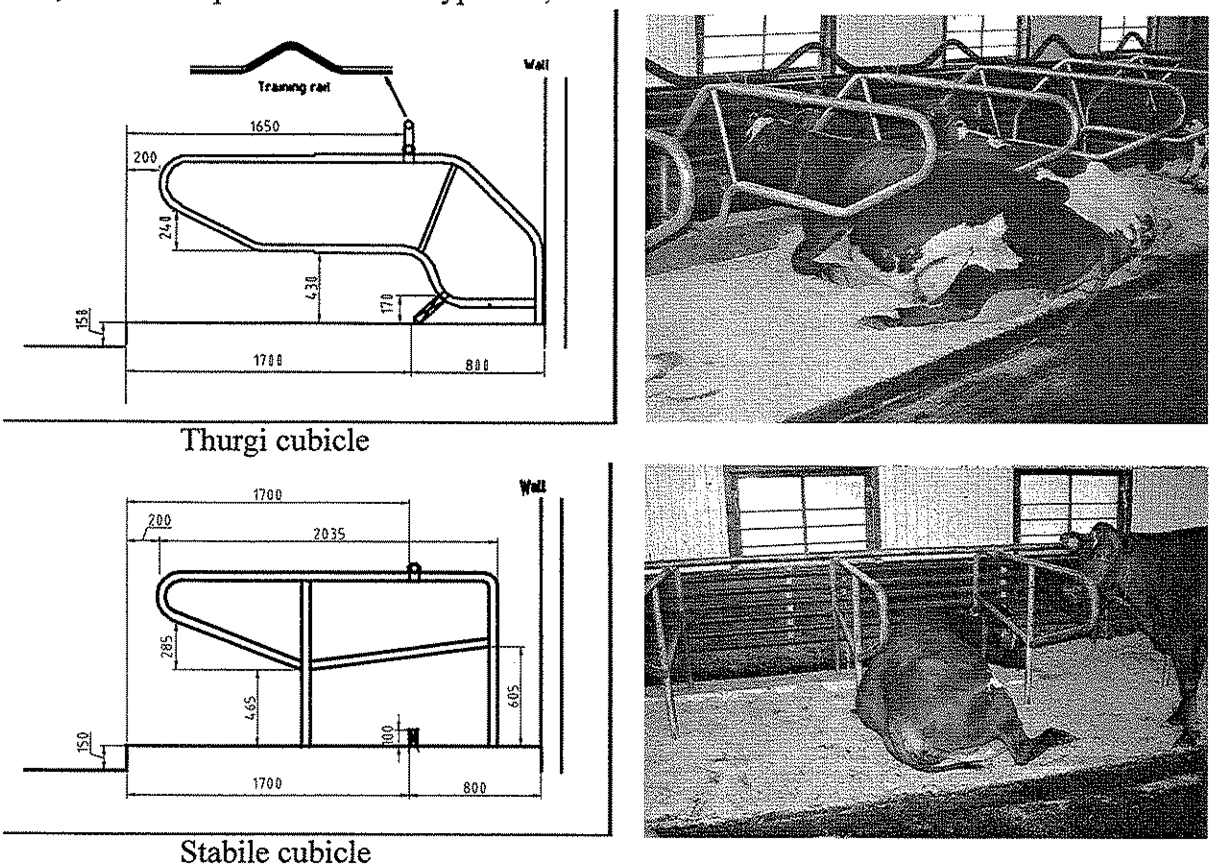


Figure 11. *The design of the cubicles used in the preference and hygiene study.*

The cows remained in the loose housing for a study period of two weeks. To determine the overall frequency of utilisation of cubicles and to establish a pattern of cubicle choice, all cubicles were continuously monitored during the last 3 days of the study period. Analyses were made on lying time and standing time, separating standing with two feet and four feet on the cubicle floor. Observations were made every 5-min and the occupancy level in each cubicle was noted. When using this method, activity for the following 5-min was assumed to be the same.

During the last week of the study period, a hygiene study was also made of the cubicles, determining the level of hygiene in each cubicle by observing cubicle dirtiness. Each morning and each evening, during the week, the stable personnel, as described below, evaluated cubicle cleanliness when they cleaned the cubicles. In addition, the opinions of the staff regarding the hygiene level and the cleaning properties of the different cubicles were collected.

Cleanliness data were collected on:

- The number of cubicles with faeces having a diameter of ≥ 0.1 m
- The number of cubicles having dispersed dirt

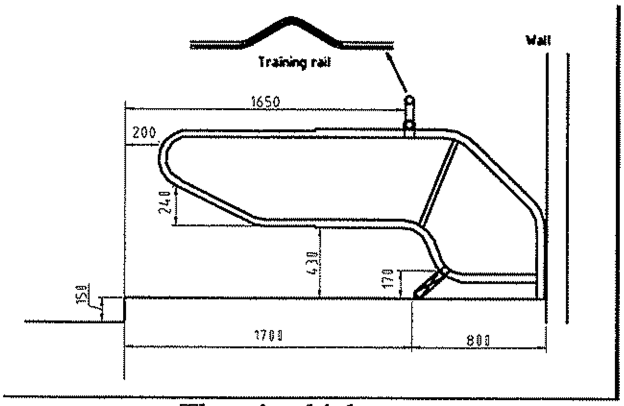
Dispersed dirt could be described as scattered faeces or dirt carried into the cubicle.

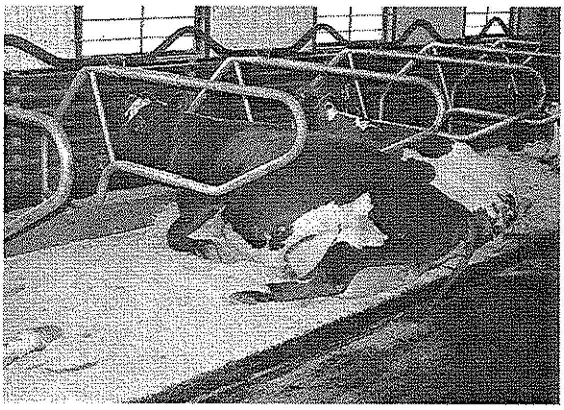
Behavioural study

Four cubicle designs were examined concerning the lying down and rising behaviour. The different partition types (see Figure 12) were installed in the cubicle barn after the preference and hygiene studies had been completed. Sixteen cows remained in the loose housing for a study and adaptation period of two weeks. During the last four days two cows, at their first and third lactation, were randomly chosen for the intense behavioural study. The first lactation cow had a body weight of 600 kg and height at withers and body lengths were 1.36 and 1.68 m, respectively. The third lactation cow had a body weight of 649 kg and height at withers and body length was 1.40 respectively 1.62 m. The two cows were grouped together separately and had only access to lie down in one type of cubicle for 24 hours. They were moved between the cubicle types and monitored for 24 hours in each of the four cubicle types.

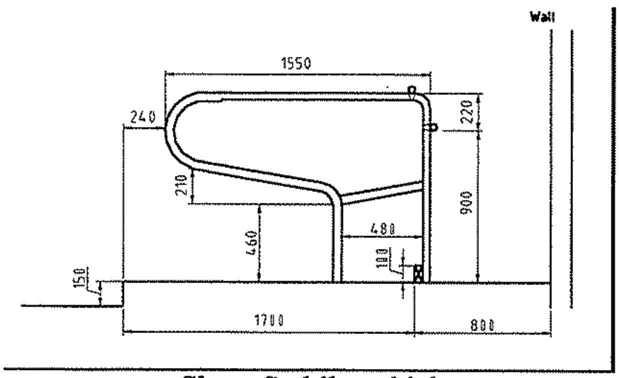
The behaviour of the cows was evaluated according to the lying down and rising sequence. Using a time-lapse recorder, the behaviour could be followed precisely, since hours, minutes and seconds were indicated on the video display. Specific behaviours were analysed according to the duration of time doing a specific behaviour, the number of intentions and attempts to perform that behaviour and the number of disturbed lying downs and rising, all in accordance with the description below.

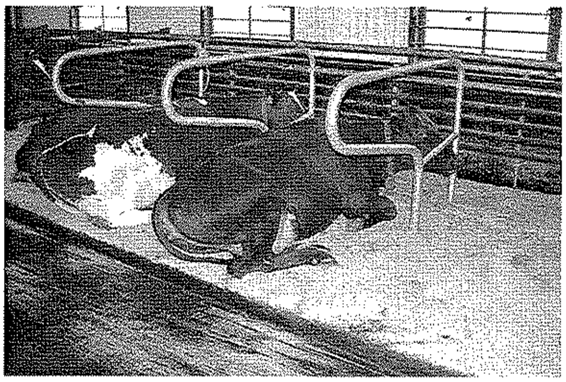
The lying down sequence was divided into several steps. The preparation time was the period from when a lying down sequence started until the first knee of the cow was in contact with the floor. This sequence started when the cow was swinging her head from side to side, with her muzzle close to the ground. However, an observation started a maximum of 300 seconds before lying down. An intention was recorded if the cow's head was lifted for more than ten seconds during the preparation time. If the lying down behaviour was interrupted and the cow got up from her knees an attempt was registered. The lying down movement was registered from the kneeling until the lying down action was completed. The rising sequence started at the occasions the cow began to pull her feet under herself and move her head forward or sideways. The rising movement ended when all four feet were in contact with the floor, and the cow was standing in a balanced position. The duration of each time the dairy cows spent lying, and when their lying down and rising behaviours were disturbed was also noted during the study. A disturbed behaviour occurred when the hind part lay down first or when the cow was rising like a horse, where the forequarters first came up in one action.



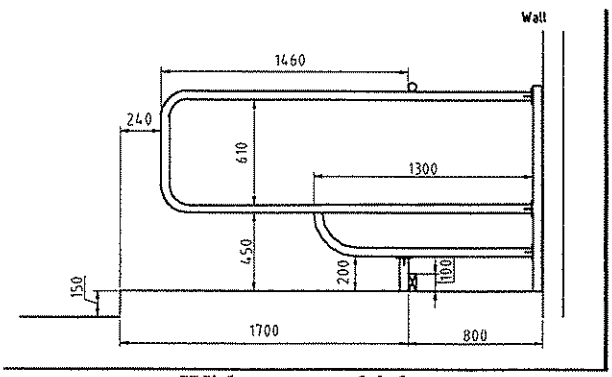


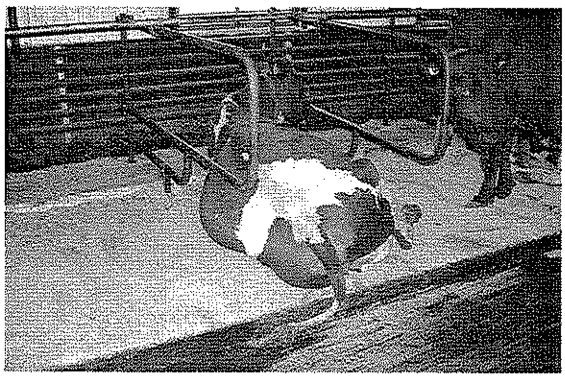
Thurgi cubicle





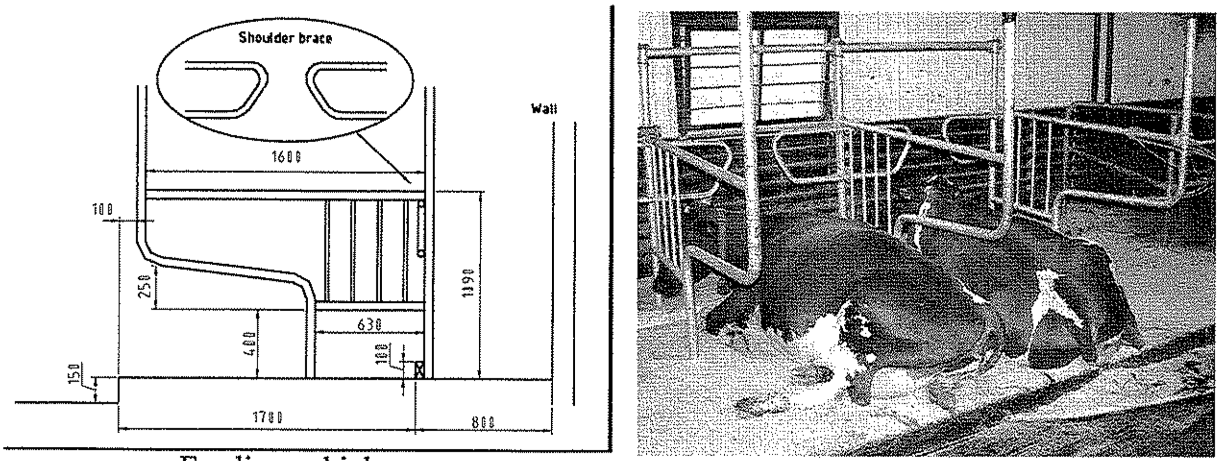
Short-Stabile cubicle





Wide-span cubicle

Figure 12 (cont.). *The designs of the cubicles used in the behavioural study.*



Feeding cubicle

Figure 12 (cont.). *The designs of the cubicles used in the behavioural study.*

Statistical analyses

Preference study

The occupancy data for each cubicle type was processed in order to present the data in percentages of observation time. Analysis of variance was done using a GLM-procedure of the SAS statistical program (SAS, 1994). Since all cubicles were in one row and no repetition was done the cubicle preference was determined by comparing the frequency distribution between the two types.

Hygiene study

The data collected was described as the amount of faeces or dispersed dirt in the cubicle type. The data was statistically processed by analysis of variance using a GLM-procedure. Interactions between dirtiness versus partition design and dirtiness versus morning and evening observations were tested. The means of the morning and evening observations were summarised.

Behavioural study

The statistical analysis of the data, which was stated as a balanced incomplete block design, was carried out using a GLM-procedure of SAS statistical program (SAS, 1994). The data from the two cows for each cubicle design were summarised and mean values calculated. Interactions between cubicle design, cow number and the individual cow were compared for statistical correlation.

carried out by a first lactation cow that was not participating in the study. This was because the cows included in the experiment were mixed for a short period with other cows. However, this was not considered to influence the results of the study. The preparation time required by the cows to lie down was significantly shorter in the Thurgi and Wide-span cubicle than in the other cubicles (Short-Stabile and Feeding-cubicle). The cows showed significantly more intentions for lying down in the Feeding-cubicle than in the Wide-span. The rising time was significantly longer in the Thurgi cubicle than in the Wide-span and Feeding cubicle. There was also a significant difference in rising time between the Short-Stabile cubicle and the Feeding-cubicle. Both the cows observed in the experiment reacted with a similar behaviour in the same type of cubicle. Therefore, their data could be processed together. Summarised in each kind of cubicle type, the total lying period was almost the same for the two cows of first and third lactation. However, a shorter duration of lying was observed for the first lactation cow.

Table 11. *Lying down and rising behaviour of two dairy cows in four cubicle designs*

	Thurgi		Short-Stabile		Wide-span		Feeding-cubicle		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	P>F
Number of lying down/rising studied	20		18		20		20		
Intentions per lying down	0.45	0.7	0.67	0.6	0.30[c]	0.5	0.75[d]	0.9	c-d<0.05
Preparation time per lying down (s)	77[a]	75	168[b]	81	73[c]	52	119[d]	75	a,c-b<0.01 a,b-d<0.01
Lying down (s)	7.0	1.5	7.4	3.0	7.4	1.6	6.8	1.3	
Rising (s)	11.3[a]	7.0	11.0[b]	3.8	10.0[c]	2.2	8.9[d]	1.7	a-c,d<0.05 b-d<0.05
Duration of each lying period (min)	80	40	78	48	69	47	78	38	

Values in rows with different superscript differ significantly

Discussion

Preference and hygiene study

The cows preferred lying in the Stabile cubicles to the Thurgi ones, probably for many different reasons. The result might indicate that cows have a preference for partitions with space sharing to the side. O'Connell et al. (1991*b*, 1992) in earlier studies found that cows seemed to be able to perceive space and frequently chose cubicle designs that allowed more space sharing to the side. Conclusively, with open frames cows can use more space laterally. However, cows may lie down diagonally and disturb neighbouring cows.

In the present study, cubicles at the extremities of the barn were preferred to the innermost and mid-way cubicles (see Appendix 2). In contrast, O'Connell et al. (1992) had the highest occupation midway in the row. A trend that was not influenced by partition type. The distribution of occupation in the present study, that favours the Stabile cubicle, might be due to the parlour placement in the barn. Cows seemed to prefer standing in the alley close to the parlour. Nonetheless, all 16 cubicles were occasionally totally occupied by the cows. During the observation time, cubicle fidelity was experienced as low, since the same cows were seen lying down in both types of cubicles.

Another reason for the given result could be that the adaptation time for the Thurgi cubicle was only two weeks. The cows had become accustomed to the Stabile cubicle, which had existed for many years. In addition, the brisket board in the Thurgi cubicles was a little too high when installed, which might have been an obstacle for the cows. The stall personnel were of the opinion that the cows became more and more used to the Thurgi cubicles.

There was no significant difference between the Thurgi and the Stabile cubicles in the occupancy level based on standing. However, in relation to total occupancy (lying and standing) there was a slight tendency for standing, both with two legs and with four legs, in the Thurgi cubicle. The higher curved training rail seemed to be favoured, and cows were subjectively standing straighter in the Thurgi cubicle. A longer experiment needs to be carried out to determine the consequences of the curved training rail.

There was only a slight tendency for more faeces and dirt in the Stabile cubicle. Nonetheless, throughout the observation time more cows were seen lying down diagonally in the Stabile cubicles than in the Thurgi cubicles. Especially, when no neighbouring cows were lying. To determine significant results a longer experiment needs to be done. It would also be interesting to find out the correlation between individual cow- and cubicle-cleanliness.

The cleanliness of the cubicles could be correlated with occupancy level. Since the occupation of the Stabile cubicles was higher, more faeces could be left on the cubicle floor. The cows were also seen using contaminated cubicles. In addition, heavier cows are higher in rank and chose cubicles first (Wierenga, 1991) and also have a preference for cubicles with more space sharing (Gwynn et al., 1993). Herlin (1994) found that older cows contaminate their cubicles more, due to defecating while lying. However, cubicle fidelity was experienced as low in the present study and young and old cows were lying mixed. Not many buttings and disturbances were seen throughout the study. It seemed as if more first lactation cows, that had a lower weight, were lying down with unsatisfactory position, e.g. diagonally or too far forward, especially in the Stabile partition, in comparison with the older cows.

Behavioural study

Several authors (Hedrén, 1971*a*; Krohn & Munksgaard, 1993; Herlin, 1994) support the connection of improved cubicle comfort and lying down behaviour. In well constructed cubicles it is considered that the cows do not to any great extent associate lying behaviour with pain, anxiety or lack of control. Herlin (1994) suggests the relation to dirtiness. Faecal contamination of cubicles is due to cows defecating while lying and well-made partitions facilitate cubicle cleanliness.

The duration of each lying period and the total lying time per 24 hours was almost the same in the four types of cubicles. This is supported by earlier studies which found that once a cow chose to lie in a cubicle, she spent a similar amount of time in it regardless of type (O'Connell et al., 1992). Krohn & Munksgaard (1993) found that the increased lying-down time between the first lactation and the third lactation was mainly caused by longer time spent on the examination of the lying place and was probably a result of higher age and live weight. This also occurred in the present study.

The behavioural study indicated that the Thurgi and Wide-span cubicles facilitated lying down behaviour since the lying down preparation time was shorter and there were fewer intentions per lying down. When studying the lying down pattern, the cows seemed to prefer lunging to the side along the brisket board in all cubicle types. In the Thurgi cubicle they occasionally put their head under the lower rail instead of lunging over the brisket board. This was similar with the Feeding-cubicle and the shorter Stabile, where they sometimes lunged through the square opening in the partition just behind the brisket board. The Feeding-partition and the Thurgi partition were occasionally hit by the cows' hip when lying down. In addition, cows were sometimes lying diagonally in the Feeding-cubicle and in the Short-Stabile cubicle. When deciding how to lie down, the lying down time (from the kneeling until the lying down action was completed) was almost the same in all cubicle types. The lower training rail in the Short-Stabile and the shoulder brace in combination with the tight partition in the Feeding-cubicle were probably obstacles when lying down.

The rising time differed between the cubicle types. The longer rising time in the Thurgi partition might be due to the higher brisket board. In addition, the open hip zones in the Feeding-cubicle and the Short-Stabile would facilitate rising behaviour. Herlin (1994) suggested that the getting-up behaviour time is not a good indicator of animal welfare. It is in poorly designed tie-stalls or cubicles, where rising behaviour is physically hindered, that a frequent use of disturbed movement patterns upon rising, such as rising like a horse, will occur. In the present study, accurate space for the rising lunge was provided.

GENERAL DISCUSSION

From the literature survey it can be concluded that designing cubicles for loose housed dairy cows is complex. Internationally, and also in Sweden, there is great variation in cubicle design. However, requirements are generally the same and the recommendations tend to be increasingly uniform. Generally, cow comfort is favoured and becomes more important for successful dairy housing. Still, cubicle design is a compromise between comfort, cleanliness and economy.

The movements and dimensions of the cow are more discussed today and strongly related to equipment design. However, there is no solution in cubicle design that will fit all cow weights. The cows will remain very different in size and the biggest and smallest cows are setting the limits. By separating various cow sizes into different groups, cubicle design could be simplified, but there are many other reasons for grouping the cows, besides size. However, it might be possible designing an ideal partition shape that would be varied with different cow sizes.

Many factors will influence the ambient environment in the cubicle. A housing system can comprise a number of different designs and might exclude or include details that influence the incidence of a certain detriment or disadvantage. In addition, well-performed management is of paramount importance.

The overall conclusion made from the experimental part is that long-term experiments need to be done to evaluate how cubicle design interacts with cow cleanliness and comfort. The behaviour of cows in cubicle systems corresponds to many constraints that need to be defined and held equal. However by observation, it seems to be easier to evaluate how well the animals perform natural behaviours in the cubicles than making conclusions about cleanliness and injuries.

On the basis of the results and discussion made in the experimental part it can be concluded that partition design interacts with preference and lying behaviour of the cows. Cows seem to prefer open constructed partitions, especially in the head zone, for making a side lunge when lying down. The feeling of space to the side for the head should probably be increased and desired because of the cow regarding the brisket board as an obstacle. A high placement of the training rail also adds cubicle comfort. Anyhow, the use of a shoulder brace in the cubicle did not add lying comfort in the present experiment.

The shape of the partition will be decisive for how the cow lies down. The back of the partition could force the cow to lie down without space sharing with the neighbouring cubicle or without a diagonal lying position. As long as the front of the partition is satisfactory, cows will still have a preference for such cubicles. However, the partition could harm their hip.

Throughout the work a number of farm visits were made where it was noted that cleanliness of the cows is dependent on many things, such as management and bedding. The behaviour of the animals is not something that is primarily observed by farmers, since they react and observe cow cleanliness more. Due to other reasons than body size, cows are grouped together in the same size of cubicles, making especially small cows lie down in an unfavourable position that facilitates cow- and cubicle-dirtiness.

Cubicle width and side space sharing are probably connected. CIGR recommend a cubicle width of 1.15 m for a 650-kilo cow together with the CIGR recommended partitions (Owen et al., 1994). The functional width of the CIGR cubicle is even wider since, e.g. the hips can use space in the neighbouring cubicles. CIGR also relate their recommendations more in accordance to dairy cow body size than, e.g. the Swedish Animal Welfare Regulations. The width of the animals is not increased as much as the length when the cows become heavier.

Wider cubicles are commonly used together with partitions that follow the CIGR-recommendations, even for a 650-kilo cow. When wider cubicles are combined with the CIGR-designed partition, the cows are able to lie down diagonally. Thus a less open partition can be designed with preserved comfort if the cubicle floor dimensions are provided.

Making a cubicle attractive to the cow but still facilitating cleanliness is the main objective. The brisket board will probably facilitate cubicle cleanliness but will be an obstacle for the cow. Thus, the hypothesis that partitions with obstructed side zones perform as well as a partition that facilitates space sharing to the side could not be confirmed. A Wide-span partition facilitates space sharing to the side at the front and might position the cow at the back, which was also indicated by the Wide-span cubicle used in the test. According to McFarland (1998), cows could lie down slight diagonally but in the favoured position. However, by having a Wide-span partition that is too open, the cows might get caught. Conclusively, more experiments and research have to be made but according to the experience in this study the Wide-span partition would best facilitate cow comfort and cubicle cleanliness.

ACKNOWLEDGEMENTS

The most rewarding part of making this study has been the contact with many interesting people. Their support and willingness to share ideas have made this study possible.

Most of all, I thank my supervisor Prof. Christer Nilsson, Department of Agricultural Engineering. I would also give my special thanks to Bengt-Göran Mårtensson, Alfa Laval Agri AB, and Lennart Bengtsson, Department of Agricultural Engineering, for support and for their helpful suggestions throughout the project.

Alfa Laval Agri AB initiated this work and I am very grateful for their financing of it.

I also thank my opponent Jan Olofsson, Department of Animal Nutrition and Management, for his encouragement and also for his contribution of practical experience during the experimental part. The personnel at Kungsängen Animal Husbandry Research Centre have helped me in many ways that are highly appreciated.

Finally, the friendly atmosphere at the Department of Agricultural Engineering, especially between the students, has given me a lot of inspiration.

SAMMANFATTNING

Liggbås för mjölkkor i lösdrift – Mått och liggbåsavskiljare för renare och friskare kor

Idag används liggbås i allt större utsträckning för mjölkkor i lösdrift eftersom arbetsåtgång och ströanvändning då kan reduceras. Utformningen av en kos liggplats bör grunda sig på att dess närmiljö ska ge en god hälsa, en hög juverhygien samt möjlighet till ett naturligt beteende. Det förekommer stora skillnader i utformningen av liggbås, vilka i varierande grad uppfyller de högt ställda kraven, både i Sverige och utomlands. Problem på grund av dålig renhet, onaturliga beteenden samt skador hos kor i liggbås förekommer i alltför stor omfattning.

Detta arbete syftade till att finna en utformning på liggbåsavskiljare, samt mått för ett liggbås, för att ge rena och friska kor med ett bibehållet naturligt beteende. Detta arbete har utförts som en litteraturstudie samt genom försök. Dessutom har forskare, lantbrukare samt Alfa Laval Agri AB:s marknadsavdelningar kontaktats för ytterligare synpunkter och information. Utformningen av liggbåsets golv har visserligen stor betydelse för liggbåsets funktion men det har endast behandlats i en översiktlig omfattning.

Forskningsresultat och rekommendationer för liggbås har sammanställts i litteraturstudien. Olika delar och funktioner har diskuterats utifrån kons och skötarens förutsättningar. De liggbås vilka idag finns tillgängliga på marknaden finns med i en enkel översikt, där erfarenheter från de olika modellerna bifogats.

Utgående från en 650 kg mjölkko, av tung ras, kunde följande rekommendationer sammanställas:

- Liggbåsets liggyta bör vara väl upphöjd över gödselgången för att förbli ren. Bakkanten ska vara ett mothåll vid utgödsling (skrapad gång) och tillräckligt hög för att kor inte ska backa in i båset. En för hög kant kan hindra kor att använda båset medan en för låg kant gör liggytan svårdefinierbar för kon. 0,2 till 0,25 m rekommenderas (det lägre vid dränerande golv).
- Liggbåsets bredd är beroende av avskiljarens utformning. Ett bredare bås än 1,2 m är attraktivt för kon men kan resultera i en diagonal liggställning, vilket kan försämra renheten.
- Liggbåsets "ligg"-längd bör motsvara kons kroppslängd plus extra plats för att röra sig under läggning och resning. 1,7 m rekommenderas.
- Huvudutrymmet bör vara väl tilltaget för framåtresning. 0,8 m rekommenderas.
- Liggbåsets totala längd bör enligt ovanstående vara 2,5 m.
- Om bröstplanka används ska den placeras 1,7 m från liggbåsets bakkant. Bröstplankan bör inte vara högre än 0,15 m och ha en lutning framåt, från lodlinjen, på 30 grader för att inte skada eller hindra kon.
- Lutningen på liggbåsets liggyta, från framkant till bakkant, bör vara 4 % för att få ett väldränerat bås och hålla kon liggande mot bakkanten.
- Liggytan bör vara mjuk, ren och torr men fortfarande tillräckligt hård för klövarnas tryck. Materialet ska vara hygieniskt, dock inte halt, och försett med lämpligt strömaterial.
- Det horisontella avståndet mellan avskiljarens bakkant och gödselgången bör vara 0,25 m.

Detta för att arbete och kotrafik i gången inte ska kollidera med avskiljaren som fortfarande måste styra kon rätt när hon går in i båset.

- Nackbommen bör placeras 1,2 m över liggbåsets golv och på samma horisontella avstånd som bröstplankan.
- Avskiljarens övre rör bör vara i ögonnivå på kon när hon går in i båset. Det övre röret placeras 1,1 - 1,2 m över båsytan men är i övrigt beroende av hur övriga avskiljaren ser ut.
- Avskiljarens nedre rör bör sättas så att det definierar kons liggplats under läggningen. Samtidigt ska det inte hindra kon vid resning eller hindra de naturliga liggställningarna. Tre vanliga rekommendationer visas i Figur 13.
  1. CIGR rekommenderar en utformning som baserar sig på tre fria zoner för huvud, ben och bakkropp.
  2. En vanligt förekommande rekommendation är att det nedre röret ska vara placerat 0,35 till 0,45 m över liggbåsets golv.
  3. "Wide-span" avskiljare följer liggbåsets golv i fronten men styr kons bakkropp mer.

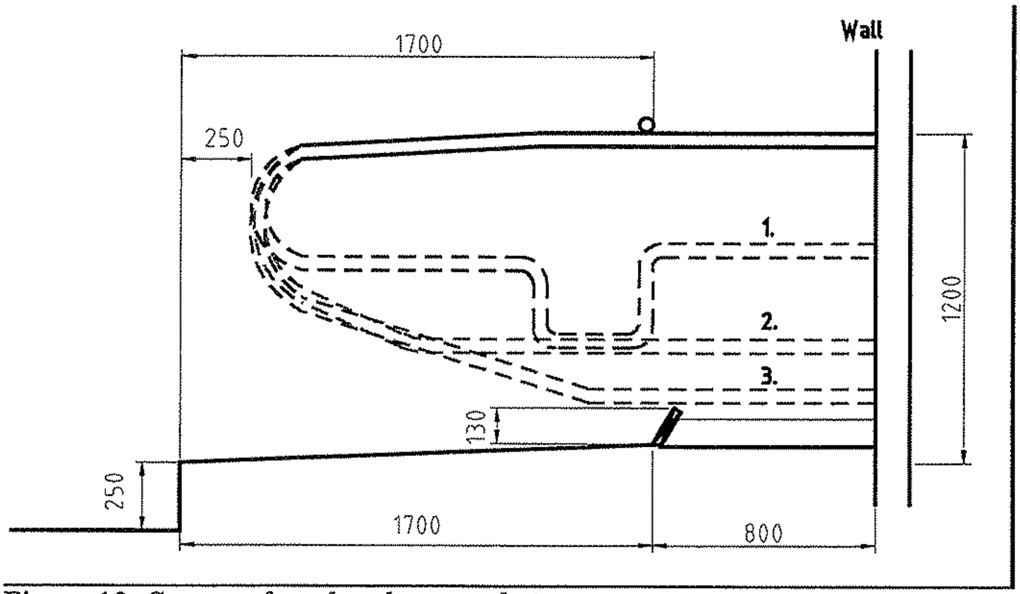


Figure 13. *Sammanfattade rekommendationer.*

I fältstudien användes preferensstudier, hygienstudier och beteendestudier för att utvärdera de olika utformningarna. Videofilmning av kor har tidigare visat sig vara en bra metod för att undersöka hur väl ett bås är utformat. Hypotesen var att ett liggbås med tätare avskiljare i sidan resulterar i bättre renhet och komfort än ett mer öppet bås. Ett annat syfte var att jämföra och se om nackbommen i ett liggbås kunde utformas annorlunda för att bättre stimulera naturligt beteende men samtidigt vara funktionell.

I preferens och hygienstudier jämfördes två utformningar av liggbås. Två, på marknaden redan existerande, liggbåsavskiljare kombinerades med bröstplanka och nackbom. 8 bås av vardera modell användes för 16 mjölkkor. Hygienen i liggbåsen observerades manuellt genom att notera eventuell gödselförekomst två gånger per dygn under en vecka. I beteendestudien jämfördes fyra utformningar av liggbås med avseende på kons möjlighet att genomföra normala och obehindrade läggnings- och resningsrörelser. Två slumpmässigt utvalda mjölkkor specialstuderades under ett dygn (efter anpassningsperiod) i vardera av de olika liggbåssystemen. Samma två kor användes hela tiden. Samtliga utvärderingar gjordes med hjälp av time-lapse recording.

Studier av komfort och renhet i liggbås, med lätt tolkningsbara resultat, är svåra att genomföra. Många faktorer inverkar och långa försöksserier med konstanta variabler är nödvändiga. Det förefaller vara lättare att intensivstudera beteenden än renhet, även om lantbrukare oftare observerar renheten på sina kor.

Enligt undersökningsresultaten verkar nackbommens utformning och placering ha effekt på liggbåsets funktion. En högre placerad nackbom förbättrade beteendet i liggbåset. I denna undersökning föreföll däremot ett bogstöd vara till hinder för kon.

Ett liggbås med avskiljare som har mer sidoplats i framdelen, verkar vara mer attraktivt och hindrar inte kon från att utföra en naturlig läggning. En lägre utformning av avskiljarens bakre del verkar kunna styra kon till en liggposition som resulterar i renare kor. Hypotesen att en avskiljare ska ha täta sidozoner höll därmed bara delvis och försöksresultaten tyder på att avskiljaren ska utformas med öppen sida i framdelen och ett relativt lågt rör i bakdelen.

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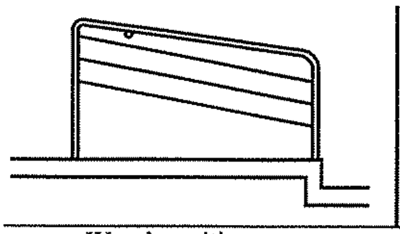
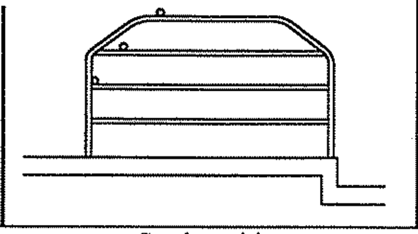
APPENDIX 1 - Examples of partition design

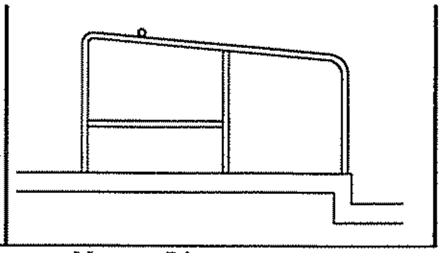
FRONT AND REAR SUPPORT



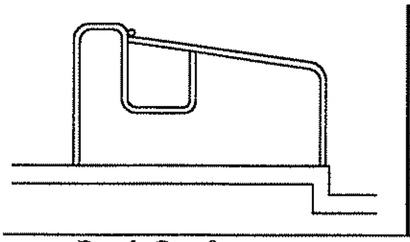
Wood partition



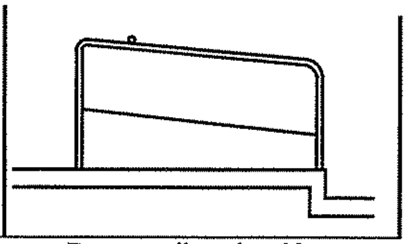
Steel partition



Newton Rigg

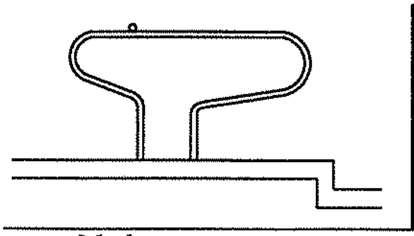


Dutch Comfort

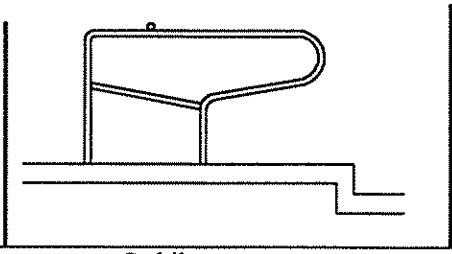


Bottom rail made with a rope

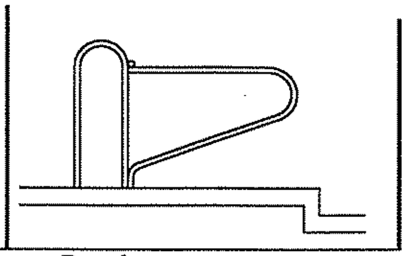
MIDDLE SUPPORT PARTITIONS



Mushroom

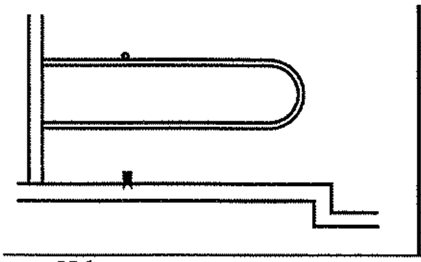


Stabile

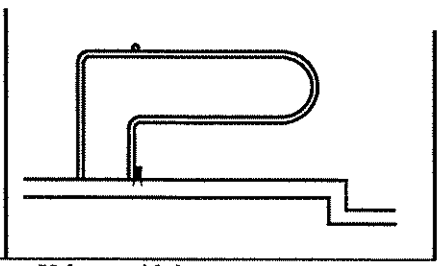


Dorsdunn

U-SHAPE

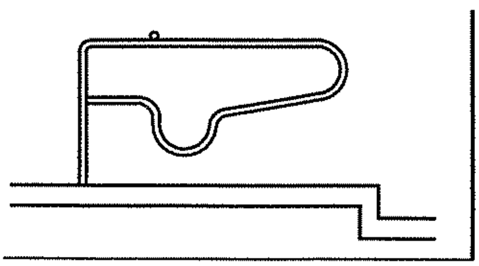


U-loop

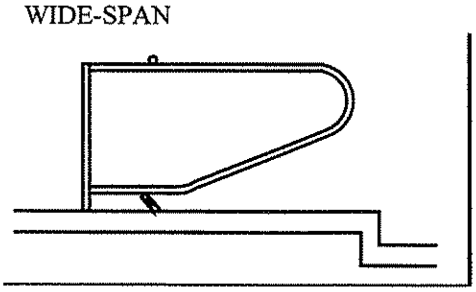


U-loop with base support

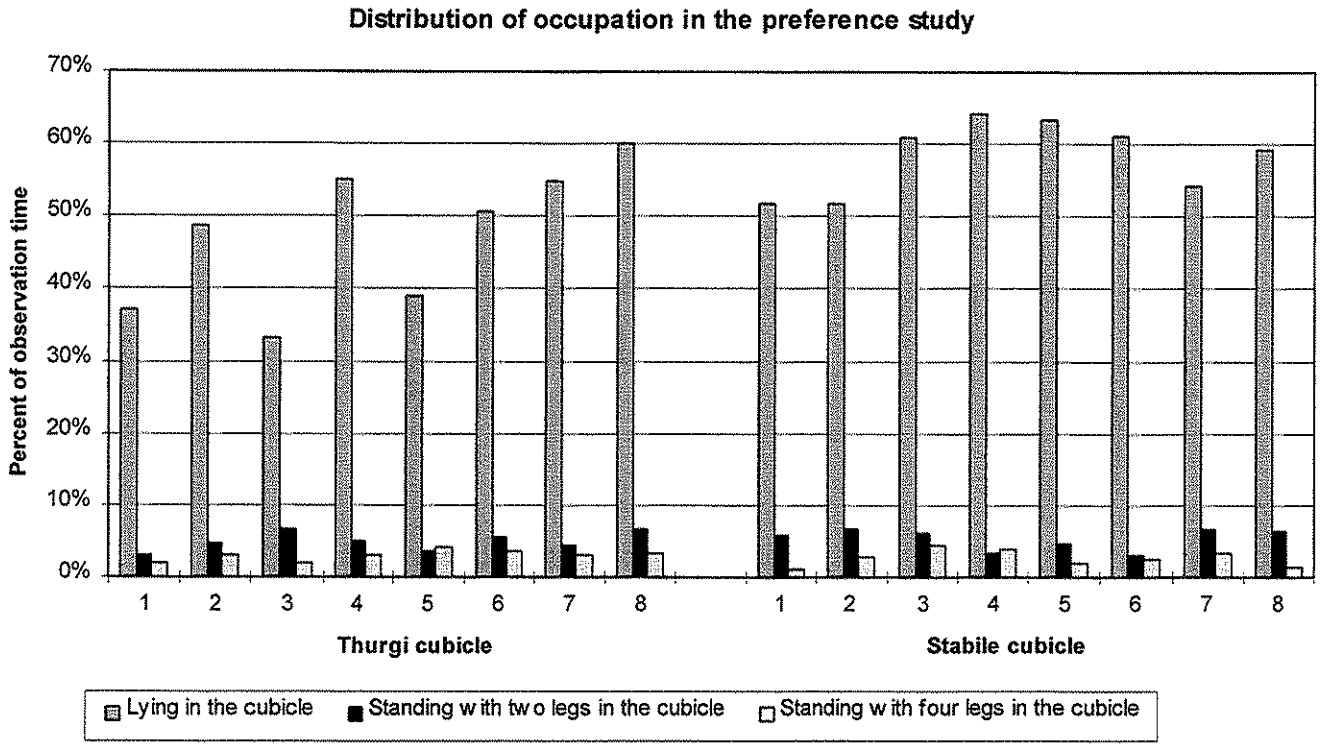
DUTCH-TYPE



WIDE-SPAN



APPENDIX 2



Distribution of occupation in the preference study
Percent of observation time
70%
60%
50%
40%
30%
20%
10%
0%
1 2 3 4 5 6 7 8
Thurgi cubicle
1 2 3 4 5 6 7 8
Stabile cubicle
Lying in the cubicle
Standing w ith tw o legs in the cubicle
Standing w ith four legs in the cubicle